Universidade
Estadual de Londrina

CAROLINA BLEFARI BATISTA

BIOGEOGRAFIA E CONSERVAÇÃO DE MORCEGOS NA MATA ATLÂNTICA

Londrina
2020

CAROLINA BLEFARI BATISTA

BIOGEOGRAFIA E CONSERVAÇÃO DE MORCEGOS NA MATA ATLÂNTICA

Tese apresentada ao Programa de Pós-graduação em Ciências Biológicas da Universidade Estadual de Londrina - UEL, como requisito parcial para a obtenção do título de Doutor.

Orientador: Prof. Dr. Marcos Robalinho Lima.
Co –orientador: Prof. Dr. Isaac Passos de Lima.

Londrina
2020

Ficha de identificação da obra elaborada pelo autor, através do Programa de Geração Automática do Sistema de Bibliotecas da UEL

Batista, Carolina Blefari.
Biogeografia e conservação de morcegos na Mata Atlântica / Carolina Blefari Batista. - Londrina, 2020.
203 f. : il.

Orientador: Marcos Robalinho Lima.
Coorientador: Isaac Passos de Lima.
Tese (Doutorado em Ciências Biológicas) - Universidade Estadual de Londrina, Centro de Ciências Biológicas, Programa de Pós-Graduação em Ciências Biológicas, 2020.
Inclui bibliografia.

1. Banco de dados e morcegos para a região de Londrina, Paraná, Brasil - Tese. 2. Beta diversidade de morcegos na Mata Atlântica - Tese. 3. Áreas de endemismo para morcegos na Mata Atlântica - Tese. I. Robalinho Lima, Marcos . II. Passos de Lima, Isaac. III. Universidade Estadual de Londrina. Centro de Ciências Biológicas. Programa de Pós-Graduação em Ciências Biológicas. IV. Título.

CDU 574

CAROLINA BLEFARI BATISTA

BIOGEOGRAFIA E CONSERVAÇÃO DE MORCEGOS NA MATA ATLÂNTICA

Tese apresentada ao Programa de Pós-graduação em Ciências Biológicas da Universidade Estadual de Londrina - UEL, como requisito parcial para a obtenção do título de Doutor.

BANCA EXAMINADORA

Orientador: Prof. Dr. Marcos Robalinho Lima
Universidade Estadual de Londrina - UEL

Profª. Drª. Silvia Helena Sofia
Universidade Estadual de Londrina - UEL

Prof. Dr. Fernando Camargo Jerep
Universidade Estadual de Londrina - UEL

Prof. Dr. Ubirajara de Oliveira
Universidade Federal de Minas Gerais - UFMG

Prof. Dr. Carlos Barros de Araujo
Universidade Estadual de Londrina - UEL

Londrina, 29 de maio de 2020.

AGRADECIMENTOS

Aos Professores Doutores Marcos Robalinho Lima e Isaac Passos de Lima, meus respectivos orientador e coorientador, por terem me acompanhado por todos os quatro anos de doutorado, esclarecido minhas ideias e contribuído sempre de maneira construtiva para a tese e para meu crescimento como pesquisadora e acadêmica.

Ao Prof. Dr. Nelio Roberto dos Reis, que me acolheu em seu laboratório na UEL no começo do meu mestrado, esteve presente em parte do meu doutorado e é o responsável por abrir tantas portas para o meu trabalho com ecologia e conservação de morcegos.

À minha banca de qualificação, Dr. Luís dos Anjos, Dr. Efraim Rodrigues e Dra. Thaís Pires Miranda. E a minha banca de defesa, Dra. Silvia Helena Sofia, Dr. Fernando Camargo Jerep, Dr. Ubirajara Oliveira e Dr. Carlos Barros de Araújo.

Aos amigos de profissão que contribuíram para meu desempenho como doutoranda, em especial Gisele Porto, Dr. Alan Deivid Pereira, Dr. Guilherme de Toledo Figueiredo, Dr. Rafael Arruda e Dr. Carlos Roberto Abrahão. Aos colegas de laboratório (EECon Lab UEL) Ricardo Adelino, Dra. Larissa Calsavara e Dr. Guilherme Willrich. Aos vizinhos de laboratório Dr. Gabriel Medina Rosa e Dra. Tatiana Motta Tavares.

Aos coordenadores da Pós Graduação em Ciências Biológicas da UEL, Dr. Fernando de Camargo Jerep e Dr. Edmilson Biachini. À equipe técnica e administrativa do Centro de Ciências Biológicas da UEL, em especial ao técnico Edson Santana da Silva e a secretária da Pós Graduação em Ciências Biológicas, Nazária Bertola Duarte.

Aos policiais ambientais que ficam cediados no Jardim Botânico de Londrina e aos guardas do campus da UEL, por garantirem a minha segurança em campo. Ao proprietário da Fazenda da Mata do Bule e seu funcionário, Pelé, por permitirem minha pesquisa na área.

À toda equipe do LEPIB, UEL, pelos cafés, discussões de ideias e passatempos.

Ao apoio da minha família, especialmente minha mãe e meu pai, sem o qual eu não seria a Carol que sou hoje.

O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Código de Financiamento 001

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001

“Explicar completamente a natureza é uma tarefa difícil demais para qualquer homem, e mesmo para qualquer época...
É muito melhor fazer um pouco com certeza e deixar o resto para os que vierem depois do que explicar todas as coisas por conjectura sem se certificar de nada...”
(Isaac Newton)

BATISTA, C. B. **Biogeografia e conservação de morcegos na mata atlântica**. 2020. 219 f. Tese (Doutorado em Ciências Biológicas) – Universidade Estadual de Londrina, Londrina, 2020.

RESUMO

Entender como as espécies estão distribuídas no espaço, quais são os fatores limitantes de suas distribuições, e como isso tudo varia de acordo com a escala de análise, é importante para ajudar a prever a dinâmica das populações em resposta às mudanças climáticas e outras perturbações no ambiente. Essas informações são úteis para guiar o planejamento da conservação prática, de forma a aumentar a eficiência da relação custo-benefício nos investimentos à longo prazo. Para compreender padrões de distribuição é necessário que a base de dados de ocorrência de espécies utilizada nas análises seja uma fonte confiável e atualizada, com o máximo de informações precisas (ex. taxonomia, local georreferenciado, indicação do esforço amostral). Dessa forma, o primeiro capítulo objetivou revisar as ocorrências de morcegos para a região de Londrina, Paraná, nos últimos 36 anos, e compilar um banco de dados com informações sistematizadas, além de identificar as lacunas de amostragem para ajudar a direcionar onde e como novos esforços devem ser empregados. Essa revisão foi baseada em dados publicados e não publicados. O segundo capítulo, objetivou identificar os padrões e os preditores (ambientais e espaciais) da beta diversidade de morcegos na Mata Atlântica, em diferentes escalas de análise. Foi utilizada uma análise de particionamento da beta diversidade (em aninhamento e substituição) e um Modelo de Dissimilarirade Generalizado para correlacionar a beta diversidade com os preditores. O terceiro capítulo, objetivou responder: 1) Onde estão localizados os centros de maior concentração e restrição de diversidade de morcegos dentro dos limites do *hostspot* global Mata Atlântica? e 2) Quanto em extensão dessas áreas já encontram-se protegidas por lei? Para isso foi utilizada uma análise de Interpolação Geográfica de Endemismo (GIE) e uma sobreposição do mapa de Unidades de Conservação (UCs) ao mapa resultante da GIE. Os resultados apresentados nos três capítulos: 1- servem de base para estudos que queiram utilizar o banco de dados da distribuição de morcegos na região de Londrina; 2- Indicam que esta região ainda está subamostrada e direcionam novos esforços de amostragem para morcegos; 3- identificam as ecorregiões mais ricas em morcegos para a Mata Atlântica (costa e interior da Bahia e Serra do Mar); como a beta diversidade varia ao longo do gradiente latitudinal e longitudinal do bioma; e como a percepção dessa variação muda de acordo com a escala de análise; 4- ajudam a prever como as mudanças ambientais podem interferir na distribuição das espécies, ao indicarem a importância dos fatores ambientais na composição das espécies de morcegos; 6- apresentam uma área de endemismo para 63% das espécies de morcegos na Mata Atlântica, localizada no centro do bioma; 6- demonstra como a GIE, usando morcegos como modelo, pode ser uma análise que resulta em uma estratégia mais eficaz no planejamento das UCs na Mata Atlântica; e 7- indicam a urgência na criação de UCs dentro das regiões da costa e interior da Bahia.

Palavras-chave: Chiroptera; banco de dados; padrões de distribuição; áreas de endemismo.

BATISTA, C.B. **Bat biogeography and conservation of bats in the atlantic forest**. 2020. 219 pp. Thesis (Doctorate in Biological Sciences) – Universidade Estadual de Londrina, Londrina, 2020.

ABSTRACT

Understanding how species are distributed in space, which factors limit their distributions, and how these factos vary according to the scale of analysis, are important to help predict population responses to climate change and other environmental disturbances, for example. This information is useful to guide practical conservation planning in order to increase the cost-effectiveness of long-term investments. To understand distribution patterns, it is necessary that the species occurrence database used in the analyzes is reliable and up to date, with the maximum of accurate information (eg. taxonomy, georeferenced sites and indication of the sampling effort). Thus, the first chapter aimed to review the occurrences of bats for the Londrina region, Paraná, in the last 36 years, and compile a database with systematized information. In addition, we identified sampling gaps to help direct where and how new efforts must be employed. This review was based on published and unpublished data. The second chapter aimed to identify the patterns and predictors (environmental and spatial) of bats’ beta diversity in the Atlantic Forest, at different scales of analysis. A beta diversity partitioning analysis (in nestednees and turnover) and a Generalized Dissimilarity Model were used to correlate beta diversity with the predictors. The third chapter, aimed to answer: where are the centers of greatest concentration and restriction of diversity of bats located within the limits of the Atlantic Forest hostspot? and, how much of these areas are already protected by current legislation? For this, an analysis of Geographical Interpolation of Endemism (GIE) was used and an overlay of the map of Protected Areas (PAs) on the map resulting from the GIE. The results presented in the three chapters: 1- a data base for studies on bat distribution in the region of Londrina; 2- data indicate that the Londrina region is still under-sampled and direct new sampling efforts are needed; 3- identify the more species-rich ecoregion for the Atlantic Forest for bats (coast and interior of Bahia and Serra do Mar); explaining how beta diversity varies along the biome's latitudinal and longitudinal gradient; and how the perception of this variation changes according to the scale of analysis; 4- help to predict how environmental changes can interfere in species distribution, by indicating the importance of environmental factors in the composition of bat species; 6- identification of an endemism area for 63% of bat species in the Atlantic Forest, located in the center of the biome; 6- demonstrate how GIE, using bats as a model, can be an analysis that results in a more effective strategy in planning PAs in the Atlantic Forest; and 7- indicate the urgency of creating PAs within the coastal and interior Bahia ecoregions.

Keywords: Chiroptera; database; distribution patterns; areas of endemism.

LISTA DE FIGURAS

CAPÍTULO 1

CAPÍTULO 2

CAPÍTULO 3

APÊNDICE B

LISTA DE TABELAS

CAPÍTULO 2

APÊNDICE A

APÊNDICE B

APÊNDICE C

LISTA DE ABREVIATURAS E SIGLAS

A	Amazon
AF	Atlantic Forest
A/SE	Abundance/Sampling effort
C	Carnivorous
Ca	Caatinga
CAPES	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
CNPQ	Conselho Nacional de Desenvolvimento Científico e Tecnológico
CR	Critically Endangered
DD	Data deficient
EECon Lab	Evolutionary Ecology & Conservation Lab (Universidade Estadual de Londrina)
F	Frugivorous
GDM	Generalized dissimilarity model
GIE	Geographical Interpolation Endemism
H	Hematophagous
I	Insectivorous
ICMBio	Instituto Chico Mendes da Conservação
IN	International status conservation
IUCN	International Union for Conservation of Nature's
LC	Least concern
LEPIB	Laboratório de Ecologia de Peixes e Invasões Biológicas
MZUEL	Museu de Zoologia da Universidade Estadual de Londrina
N	Nectarivorous
NI	Not included
NT	Near Threatened

O	Omnivorous
P	Piscivorous
Pa	Pampas
PA	Protected Areas
PEMG	Parque Estadual Mata dos Godoy
PMAT	Parque Municipal Arthur Thomas
RE	Regional satatus conservation
RGB	Red, green, blue color pallet
UEL	Universidade Estadual de Londrina
UC	Unidade de Conservação
VU	Vulnerable
βsim	Turnover
βsne	Nestedness
βsØr	Total beta diversity

SUMÁRIO

APRESENTAÇÃO

O Capítulo 1 “Thirty-six years of research on bats in the region of Londrina, Brazil: what have we learned?” Encontra-se nas normas para ser submetido ao periódico “Neotropical Biology and Conservation” (Anexo A).

O Capítulo 2 “Beta diversity patterns of bats in the Atlantic Forest: How does the scale of analysis affect the importance of spatial and environmental factors?” Encontra-se nas normas e aceito no periódico “Journal of Biogeography” (Anexo B).

O Capítulo 3 ““Downscaling the Atlantic Forest biodiversity hotspot: using the distribution of bats to find smaller hotspots of conservation priority”. Encontra-se nas normas para ser submetido ao periódico “Biological Conservation” (Anexo C).

2. INTRODUÇÃO GERAL

Estudos que buscam compreender os padrões em biodiversidade têm sido cada vez mais abundantes (ex. SILVA et al., 2012; SAITER et al., 2016; ANJOS et al., 2018; LÓPEZ-AGUIRRE et al., 2019). Isso porque o aumento do impacto das atividades humanas no ambiente (principalmente fragmentação de habitat e mudanças climáticas) tem causado uma drástica defaunação quando comparado com as taxas de perda de biodiversidade animal durante eventos de extinções naturais (DIRZO et al., 2014; PIMM et al., 2014; VELLEND et al., 2017), implicando na urgência em entender os padrões de distribuição das espécies para que tomadores de decisões possam ter suporte e criar medidas visando minimizar esses impactos, e que venham a auxiliar na conservação da biodiversidade.

Com base nisso, ecologistas e biogeógrafos tentam responder, dentre outras questões, porque as espécies ocorrem em determinados locais, mas não em outros. Diversas hipóteses podem ser testadas, como a de que o ambiente impõe limitações climáticas ou de recursos (filtros ambientais), ou que as espécies evoluíram em determinados locais e não conseguiram se dispersar (DOBROVOLSKI et al., 2012; GIANUCA et al., 2017). Esta última, seja por causa da distância geográfica entre os locais ou a existência de barreiras geográficas (filtro geográfico), ou pela baixa capacidade de dispersão das espécies (filtro ecológico). Para isso é necessário entender a relação da ocorrência das espécies com o ambiente, investigando como os filtros ambientais, geográficos e ecológicos influenciam nos padrões de distribuição. Por exemplo, sabe-se que a latitude e a altitude estão relacionadas ao clima e são preditores ambientais na distribuição e riqueza das espécies (WILLIG et al., 2003; STEVENS, 2013; ARITA et al., 2014; SOININEN et al., 2018; Batista et al., 2020), sendo os locais em latitudes baixas/médias e em altitudes mais baixas, mais ricos do que as regiões mais frias em altas latitudes ou altitudes. Ainda, espécies que possuem baixa capacidade de dispersão, podem ter suas distribuições fortemente influenciadas pelos filtros geográficos (DOBROVOLSKI et al., 2012; VARZINCZAK et al., 2019).

Entender os padrões de distribuição das espécies e como os fatores ambientais, geográficos e ecológicos estruturam a biodiversidade, pode fornecer importantes perspectivas para a conservação (WRIGHT, 2005; SIGRIST; CARVALHO, 2008; CAÑADAS et al., 2014; BATISTA et al., 2020). Por exemplo, a identificação de como as espécies estão distribuídas revela quais são endêmicas, raras, ameaçadas, e onde elas ocorrem. Isso possibilita a delimitação de zonas biogeográficas com biotas únicas (ex. OLSON et al., 2001), além de indicar onde estão as áreas de endemismo (SIGRIST; CARVALHO, 2008; CARNAVAL et al., 2014; CAMPOS; LOURENÇO-DE-MORAES, 2017; OLIVEIRA et al., 2019; CASTUEIRA-OLIVEIRA et al. 2020). Também é possível prever como as espécies responderiam às perturbações ambientais em seus habitats, como às mudanças climáticas (SIMON et al., 2013; AGUIAR et al., 2016; LOURENÇO-DE-MORAES et al., 2019). Assim, diante da escassez de investimentos para a conservação, os estudos sobre padrões em biodiversidade são uma base sólida para que os conservacionistas escolham estratégias mais eficientes e com melhores relações de custo/benefício (SIGRIST; CARVALHO, 2008). Por exemplo, ao entender melhor a distribuição de espécies possibilita a indicação de áreas prioritárias para a conservação que consigam salvaguardar o máximo de espécies (de diferentes *taxa*, as raras, endêmicas e ameaçadas), serviços ecossistêmicos, ou fitofisionomias únicas em longo prazo (BRUM et al., 2017; CAMPOS; LOURENÇO-DE-MORAES, 2017; SOBRAL–SOUZA et al., 2018).

As ferramentas para investigar os padrões de distribuição das espécies estão cada vez melhores e mais acessíveis, com bons programas gratuitos que permitem medidas e modelagens de dados de biodiversidade (OLIVEIRA, 2018; SIMPSON, 2018; LORTIE et al., 2020). A princípio, apenas índices simples para medir a riqueza, diversidade e equabilidade estavam disponíveis (veja revisão em COLWELL; CODDINGTON, 1994). No entanto, as inferências que esses índices permitem fazer são limitadas para explicar as diferentes escalas de diversidade (alfa, gama e beta). A diversidade local (ou diversidade alfa) e a diversidade regional (a soma da diversidade de todos os locais dentro de uma região, ou diversidade gama) são facilmente medidas por esses índices.

Como resultado, conseguimos avaliar quais são as comunidades mais ricas ou diversas e quão semelhantes elas são entre si em uma escala regional. Mas não conseguimos analisar como a composição das espécies varia entre as comunidades dentro de uma região (diversidade beta). Existem duas maneiras pelas quais as comunidades podem se diferenciar e que compõe a medida de beta diversidade (BASELGA; ORNE, 2012). A primeira é a substituição de determinadas espécies num local por outras espécies em outro local, ou seja, ambos locais podem ter o mesmo índice de riqueza, mas a composição da comunidade é diferente. A segunda implica no aninhamento entre locais, ou seja, a perda ou ganho de espécies em determinados locais em detrimento de outros. Baseado nisso, Baselga; Orne (2012) propuseram um método que foi implementado no pacote "`Betapart`" (`R-project`) capaz de particionar a beta diversidade (em substituição e aninhamento), proporcionando uma análise mais eficiente que revela como as comunidades se diferenciam, possibilitando identificar a escala espacial da perda ou ganho de diversidade (SOCOLAR et al., 2015).

Aliar diferentes métodos de análises em biodiversidade podem fornecer informações mais complexas ainda (ex. OLIVEIRA et al., 2019). Além de ser possível identificar os gradientes de riqueza e composição de espécies entre as comunidades (a beta diversidade), podemos atribuir variáveis ambientais e geográficas ao gradiente espacial da análise, usando um Modelo de Dissimilaridade Generalizado (GDM), por exemplo. Este modelo correlaciona as mudanças das comunidades em um gradiente regional às variáveis climáticas e espaciais do habitat, sugerindo uma relação das diferenças na composição das espécies entre locais (FITZPATRICK et al., 2013; FITZPATRICK; LISK, 2016). Ainda, podemos encontrar as áreas onde ocorre a sobreposição na distribuição das espécies, indicando alta diversidade, e que possuem também espécies endêmicas (as chamadas áreas de endemismo) (ex. Interpolação Geográfica de Kernel, ou GIE - OLIVEIRA et al., 2015). Analisar a diversidade utilizando diferentes métricas em conjunto, auxilia no mapeamento de áreas de relevância biológica e pode clarear o direcionamento dos mecanismos envolvidos na conservação da biodiversidade.

Todavia, a correta aplicação desses métodos depende de um banco de dados extenso e confiável, que contenha informação sobre a distribuição das espécies com dados georreferenciados e com informações taxonômicas corretas ou ao menos que permitam a conferência de *vouchers* depositados em coleções seguras e estruturadas (DiCAMILLO et al., 2018). Atualmente diversos bancos de dados estão disponíveis (GBIF, SpeciesLink, e até os mapas da IUCN são utilizados como ocorrência de espécies) e é em parte devido a isso que tem sido possível o desenvolvimento de modelos sobre padrões de biodiversidade (SANTOS et al., 2010). No entanto, a falta de amostragens realizadas de forma padronizada (com o emprego de esforço amostral suficiente e em áreas aleatórias e não concentradas em poucos locais), as identificações taxonômicas imprecisas ou incorretas e falta de precisão dos dados georreferenciados, geram lacunas nos mapas de ocorrência e podem comprometer a validade dos modelos (HORTAL, 2008; MALDONADO et al., 2015), dificultando o trabalho de ecólogos, biogeógrafos e conservacionistas. Com base nisso, grupos de pesquisadores têm concentrado esforços em reunir os dados de ocorrência das espécies, revisar criteriosamente e compilar informação em bancos de dados confiáveis (Um exemplo é o conjunto de dados organizado pelos pesquisadores Mauro Galetti e Milton Ribeiro para o bioma Mata Atlântica "*Atlantic: Data Papers from a biodiversity hotspot*". Disponível em: https://esajournals.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1939-9170.AtlanticPapers).

A partir da compilação de dados confiáveis de ocorrência das espécies e a aplicação de modelos ecológicos e biogeográficos, diversos estudos tem indicado áreas prioritárias para a conservação, em diferentes regiões e escalas de análise (global – CEBALLOS; EHRLICH, 2006; JENKINS et al., 2013; região neotropical - SIGRIST; CARVALHO, 2008; Brasil – OLIVEIRA et al., 2019; biomas inteiros – SIGRIST; CARVALHO, 2008; CARNAVAL et al., 2014; ecorregiões - CAMPOS et al., 2017). Estudos que analisam a distribuição do mesmo *taxa* mas em diferentes escalas de análise, demonstram que a escala influencia na percepção dos resultados (STEVENS et al., 2007; STEVENS, 2013; LÓPEZ-GONZÁLEZ et al., 2015). Quanto maior a escala de análise, mais facilmente se observa a influência da distância geográfica na distribuição das espécies (VARZINCZAK et al., 2018; LÓPEZ-AGUIRRE et al., 2019). Por outro lado, análises em escalas regionais, principalmente pequenas regiões, podem superestimar a influência das variáveis climáticas locais na ocorrência das espécies, deixando de lado fatores geográficos (STEVENS, 2013; STEVENS et al., 2007; LÓPEZ-GONZÁLEZ et al., 2015). Isso ressalta a importância de se investigar os padrões de diversidade em diferentes escalas, aumentando a percepção da complexidade da distribuição das espécies que, por sua vez, facilitará os esforços de conservação das espécies e biomas. Por exemplo, atualmente são indicados 36 *hotspots* globais de biodiversidade, que são áreas com alta taxa de endemismo e grande número de espécies criticamente ameaçadas (MYERS et al., 2000; WILLIAMS et al., 2011; NOSS et al., 2015; CEPF, 2016). No entanto, essas áreas podem ser tão extensas como biomas inteiros, e a falta de interesse e recursos para a conservação, junto com a exploração econômica dos remanescentes florestais, inviabiliza a aplicação de regras que protejam um bioma como um todo, tornando imprescindível a identificação de áreas críticas dentro de uma área que já possui importância intrínseca (chamados *hotsposts* dentro de *hotspots*) (CAÑADAS et al., 2014).

A Mata Atlântica, por exemplo, é considerada um dos *hostpots* globais mais ameaçados (MYERS et al., 2000; SCARANO; CEOTTO, 2015). Possui grande extensão latitudinal (do nordeste do Brasil até o leste do Paraguai e nordeste da Argentina), abrigando dez diferentes ecorregiões que refletem um alto gradiente de diversidade (OLSON et al., 2001). Análises em escalas globais e regionais, já apontaram diversas áreas de refúgio, de alta diversidade e endemicidade dentro da Mata Atlântica para diferentes *taxa* (CEBALLOS; EHRLICH, 2006; CARNAVAL; MORITZ, 2008; SIGRIST; CARVALHO, 2008; CARNAVAl et al., 2014; CAMPOS; LOURENÇO-DE-MORAES, 2017; COSTA et al., 2018), sugerindo a criação de novas Unidades de Conservação e a manutenção das já existentes ao longo de todo o bioma (desde a Serra do Mar, no sul, até as ecorrgiões de Pernambuco, no norte), dependendo do *taxa* avaliado. No entanto, a conservação da biodiversidade não tem sido uma prioridade para os tomadores de decisões no Brasil, ao contrário, o afrouxamento das legislações ambientais (como o novo Código Florestal, lei 12.651 de 25 de maio de 2012) e recentes propostas do Ministério do Meio Ambiente para reduzir a proteção da Mata Atlântica (ver em: https://www1.folha.uol.com.br/ambiente/2020/04/salles-anistia-desmatadores-da-mata-atlantica-em-meio-a-pandemia-de-covid-19.shtml Acessado em 24 de abril de 2020), colocam em risco não apenas espécies, mas os serviços ecossistêmicos que mantém o funcionamento do bioma. Isso torna urgente o direcionamento de pesquisas que consigam identificar áreas prioritárias mais pontuais, para salvaguardar não apenas um ou outro *taxa*, mas sim locais que representem grande diversidade taxonômica e funcional de diferentes grupos. Para isso é preciso escolher um grupo cuja distribuição represente também a distribuição de outros *taxa* (OLIVEIRA et al., 2019).

Nesse sentido, morcegos podem ser um bom modelo para estudos biogeográficos e conservacionistas. Dentre os mamíferos, os morcegos — com mais de 1100 espécies — só perdem em diversidade para os roedores (SIMMONS, 2005) sendo encontrados em quase todos os continentes (com exceção dos polos). Essa diversidade não é apenas taxonômica, mas também funcional existindo espécies nectarívoras, frugívoras, insetívoras, carnívoras (incluindo consumo de peixes) e hematófagas, e que utilizam diferentes recursos do habitat (cavernas, troncos de árvores, folhagens e rochas, em matas primárias ou secundárias) (KALKA et al., 2008). Isso sugere que entender como a distribuição do grupo varia ao longo de um gradiente ambiental e apontar onde estão as áreas de endemismo, pode ser um método para identificar locais com uma complexa rede de interações implicando em alta diversidade de diferentes grupos e que poderiam ser o foco dos esforços de conservação.

Em vista desse cenário, essa tese foi estruturada em três capítulos. O primeiro, objetivou revisar os registros de ocorrência de morcegos para a região de Londrina e compilar um banco de dados com informações sistematizadas. Isso porque a região é amostrada para o grupo desde a década de 80, o que gerou números extensivo de dados dispersos em literatura publicada e não publicada (monografias, dissertações e teses). Além disso, nesse capítulo identificamos e apontamos as lacunas de amostragem a fim de ajudar a direcionar onde e como novos esforços de amostragem devem ser realizados. O segundo capítulo, objetivou identificar os padrões e os preditores (ambientais e espaciais) da beta diversidade de morcegos na Mata Atlântica, em diferentes escalas de análise (o bioma como um todo, grandes regiões, e ecorregiões dentro das grandes regiões), partindo das hipóteses: H1- A substituição de espécies está associada à distância geográfica e é o principal componente da diversidade beta no gradiente latitudinal; H2- O processo principal que determina a dissimilaridade da composição ao longo de um gradiente longitudinal (da costa para o interior) é o aninhamento; H3- As ecorregiões localizadas no sul da Mata Atlântica, em latitudes mais altas e climas mais frios, terão a menor riqueza e substituição de espécies de morcegos; e H4- As ecorregiões localizadas em latitudes mais baixas, no centro e norte, apresentarão a maior riqueza e substituição de espécies de morcegos. Finalmente, o terceiro capítulo objetivou responder duas questões centrais: 1) Onde estão localizados os centros de maior concentração e restrição de diversidade de morcegos dentro dos limites do *hostspot* Mata Atlântica? e 2) Quanto em extensão dessas áreas já encontram-se protegidas por lei?

Logo, os resultados apresentados nos três capítulos: 1- servem de base para estudos mais complexos que queiram utilizar o banco de dados da distribuição de morcegos na região de Londrina, Paraná; 2- direcionam novos esforços de amostragem para morcegos na região de Londrina; 3- apontam as ecorregiões mais ricas em morcegos para a Mata Atlântica, como a beta diversidade varia ao longo do bioma e como a percepção dessa variação muda de acordo com a escala de análise; 4- indicam a importância dos fatores ambientais na composição das espécies de morcegos e que eles devem ser levados em conta em estudos biogeográficos, ecológicos e conservacionistas; 5- apresenta uma área de endemismo para 63% das espécies de morcegos que ocorrem na Mata Atlântica; e 6- demonstra como a análise de Interpolação Geográfica de Endemismo (GIE), usando morcegos como modelo, pode ser uma análise que resulta em uma estratégia mais eficaz no planejamento de zoneamento ecológico-econômico das áreas prioritárias para conservação na Mata Atlântica.

Referências

AGUIAR, L. M. S.; BERNARD, E.; RIBEIRO, V.; MACHADO, R. B.; JONES, G. Should I stay or should I go? Climate change effects on the future of Neotropical savannah bats. **Global Ecology and Conservation**, 5, p. 22–33, 2016.

ANJOS, L.; VOLPATO, G. H.; LOPES, E. V.; WILLRICH, G.; BOCHIO, G. M.; LINDSEY, B. R. A.; SIMÕES, N. R.; MENDONÇA, L. B.; BOÇON, R.; CARVALHO, J.; LIMA, M. R. Distributions of birds and plants in ecoregions: Implications for the conservation of a neotropical biodiversity hotspot. **Austral Ecology**, 43, 7, p. 839-849. 2018.

ARITA, H. T.; VARGAS-BARÓN, J.; VILLALOBOS, F. Latitudinal gradients of genus richness and endemism and the diversification of New World bats. **Ecography**, 37, p. 1024-1033, 2014.

BATISTA, C. B., LIMA, I. P., LIMA, M. R. Beta diversity patterns of bats in the Atlantic Forest: How does the scale of analysis affect the importance of spatial and environmental factors? **Journal of Biogeography**, 00, p. 1-10, 2020.

BASELGA, A.; ORME, C. D. L. Betapart: an R package for the study of beta diversity. **Methods in Ecology and Evolution**, 3, p. 808-812. 2012.

BRUM, F. T.; GRAHAM, C. H.; COSTA, G. C.; HEDGES, S. B.; PENONE, C.; RADELOFF, V. C.; RONDININII, C.; LOYOLA, R.; DAVIDSON, A. D. Global priorities for conservation across multiple dimensions of mammalian diversity. **Proceedings of the National Academy of Sciences**, 114, 29, p. 7641–7646. 2017.

CAMPOS, F.S.; LOURENÇO-DE-MORAES, R. Anurans from the mountain chain Serra do Mar: a critical area for amphibian conservation in the Atlantic Forest, Brazil. **Herpetology Notes**, 10, p. 547-560. 2017.

CAÑADAS, E.M.; FENU, G.; PEÑAS, J.; LORITE, J.; MATTANA, E.; BACCHETTA, G. Hotspots within hotspots: endemic plant richness, environmental drivers, and implications for conservation. **Biological Conservartion,** 170, p. 282–291. 2014.

CARNAVAL, A. C.; MORITZ, C. Historical climate modelling predicts patterns of current biodiversity in the Brazilian Atlantic forest. **Journal of Biogeography**, 35, p. 1187–1201. 2008.

CARNAVAL, A. C.; WALTARI, E.; RODRIGUES, M. T.; ROSAUER, D.; VANDERWAL, J.; DAMASCENO, R; PRATES, I.; STRANGAS, M.; SPANOS, Z.; RIVERA, D.; PIE, M. R.; FIRKOWSKI, C. R.; BORNSCHEIN, M. R.; RIBEIRO, L. F.; MORITZ, C. Prediction of phylogeographic endemism in an environmentally complex biome. **Proceedings Royal Society Biological Sciences**, 281, p. 14–61, 2014.

CASTUERA-OLIVEIRA, L.; OLIVEIRA-FILHO, A. T.; EISENLOHR, P. V. Emerging hotspots of tree richness in Brazil. **Acta Botanica Brasilica**, 34, 1, 117-134, 2020.

CEBALLOS, G.; EHRLICH, P. R. Global mammal distributions, biodiversity hotspots, and conservation. **Proceedings of the National Academy of Sciences of the United States of America**, 103, p. 19374–19379, 2006.

CEPF (Critical Ecosystem Partnership Fund). 2016. **Announcing the World's 36th Biodiversity Hotspot: The North American Coastal Plain**. Disponível em: http://www.cepf.net/news/top_stories/Pages/Announcing-the-Worlds-36th-Biodiversity-Hotspot.aspx. Acessado em: 30 abril 2020.

COLWELL, R.K.; CODDINGTON, J.A. Estimating terrestrial biodiversity through extrapolation. Philosophical **Transactions of the Royal Society B: Biological**

Sciences, 345, p. 101-118, 1994.

COSTA, G.C.; HAMPE, A.; LEDRU, M.P.; MARTINEZ, P.A.; MAZZOCHINI, G.G.; SHEPARD, D.B.; WERNECK, F.P.; MORITZ, C.; CARNAVAL, A.C. Biome stability in South America over the last 30 kyr: Inferences from long-term vegetation dynamics and habitat modelling. **Global Ecology and Biogeography**, 27, p. 285–297, 2018.

DI CAMILLO, C. G.; GRAVILI, C.; DE VITO, D.; PICA, D.; PIRAINO, S.; PUCE, S.; CERRANO, C. The importance of applying Standardised Integrative Taxonomy when describing marine benthic organisms and collecting ecological data. **Invertebrate Systematics**, 32, 4, p. 794, 2018.

DIRZO, R.; YOUNG, H. S.; GALETTI, M.; CEBALLOS, G.; ISAAC, N. J. B.; COLLEN, B. Defaunation in the Anthropocene. **Science**, 345, 6195, p. 401–406. 2014.

DOBROVOLSKI, R.; MELO, A. S.; CASSEMIRO, F. A. S.; DINIZ-FILHO, J. A. F. Climatic history and dispersal ability explain the relative importance of turnover and nestedness components of beta diversity. **Global Ecology and Biogeography**, 21, 2, p. 1-7, 2012.

FITZPATRICK, M.; LISK, M. Using the R package gdm to analyze and map biodiversity patterns. **R package version 1.3.11**. 2016.

FITZPATRICK, M.C.; SANDERS, N.J.; NORMAND, S.; SVENNING, J.C.; FERRIER, S.; GOVE, A.D.; DUNN, R.R. Environmental and historical imprints on beta diversity: insights from variation in rates of species turnover along gradients. **Proceedings of the Royal Society**, 280, p. 20131201, 2013.

GIANUCA, A.T.; DECLERCK, S.A.J.; LEMMENS, P.; DE MEESTER, L. Effects of dispersal and environmental heterogeneity on the replacement and nestedness components of β-diversity. **Ecology**, 98, 2, p. 525-533, 2017.

HORTAL, J. Uncertainty and the measurement of terrestrial biodiversity gradients. **Journal of Biogeography**, 35, 8, p. 1335–1336, 2008.

JENKINS, C. N.; PIMM, S. L.; JOPPA, L. N. Global patterns of terrestrial vertebrate diversity and conservation. **Proceedings of the National Academy of Sciences**, 110, 28, p. E2602–E2610, 2013.

KALKA, M.B.; SMITH, A.R.; KALKO, E.K. Bats limit arthropods and herbivory in a tropical forest. **Science**, 320, 5872, p. 71, 2008.

LÓPEZ-AGUIRRE, C.; SUZANNE, J.H.; LAFFAN, S.W.; ARCHER, M. Zoogeographical regions and geospatial patterns of phylogenetic diversity and endemism of New World bats. **Ecography**, 42, p. 1188–1199, 2019.

LÓPEZ-GONZÁLEZ, C.; PRESLEY, S. J.; LOZANO, A.; STEVENS, R. D.; HIGGINS, C. L. Ecological biogeography of Mexican bats: The relative contributions of habitat heterogeneity, beta diversity, and environmental gradients to species richness and composition patterns. **Ecography**, 38, p. 261–272, 2015.

LORTIE, C. J.; BRAUN, J.; FILAZZOLA, A.; MIGUEL, F. A checklist for choosing between R packages in ecology and evolution. **Ecology and Evolution,** 00, p. 1-8, 2020.

LOURENÇO-DE-MORAES, R.; LANSAC-TOHA, F. M.; SCHWIND, L. T. F.; ARRIEIRA, R. L.; ROSA, R. R.; TERRIBILE, L. C.; LEMES, P.; RANGEL, T.F.; DINIZ-FILHO, J.A.F.; BASTOS, R.P.; BAILLY, D. Climate change will decrease the range size of snake species under negligible protection in the Brazilian Atlantic Forest hotspot. **Scientific Reports**, 9, 1, p. 8523, 2019.

MALDONADO, C.; MOLINA, C. I.; ZIZKA, A.; PERSSON, C.; TAYLOR, C. M.; ALBÁN, J.; CHILQUILLO, E.; RONSTED, N.; ANTONELLI, A. Estimating species diversity and distribution in the era of Big Data: to what extent can we trust public databases? **Global Ecology and Biogeography**, 24, 8, p. 973–984, 2015.

MYERS, N.; MITTERMEIER, R.A.; MITTERMEIER, C.G.; DA FONSECA, G.A.B.; KENT, J. Biodiversity hotspots for conservation priorities. **Nature**, 403, p. 853-858, 2000.

NOSS, R.F.; PLATT, W.J.; SORRIE, B.A.; WEAKLEY, A.S.; MEANS, D.B.; COSTANZA, J.; PEET, R.K. How global biodiversity hotspots may go unrecognized: lessons from the North American Coastal Plain. **Diversity and Distributions**, 2, p. 236-244, 2015.

OLIVEIRA, U. 2018. **Guia completo de uso de BioDinamica**. DOI: 10.13140/RG.2.2.26705.17765

OLIVEIRA, U.; BRESCOVIT, A. D.; SANTOS, A. J. Delimiting Areas of Endemism through Kernel Interpolation. **PLOS ONE**, 10, 1, p. e0116673, 2015.

OLIVEIRA, U.; SOARES-FILHO, B. S.; SANTOS, A. J.; PAGLIA, A. P.; BRESCOVIT,

A. D.; DE CARVALHO, C. J. B.; SILVA, D.P.; REZENDE, D.T.; LEITE, F.S.F.; BATISTA, J.A.N.; BARBOSA, J.P.P.P.; STEHMANN, J.R.; S.ASCHER, J.; VASCONCELOS, M.F.; MARCO, P.; LÖWENBERG-NETO, P.; FERRO, V. G. Modelling Highly Biodiverse Areas in Brazil. **Scientific Reports**, 9, 1, p. 6355 2019.

OLSON, D.M.; DINERSTEIN, E.; WIKRAMANAYAKE, E.D.; BURGESS, N.D.; POWELL, G.V.N.; UNDERWOOD, E.C.; D'AMICO, J.A.; ITOUA, I.; STRAND, H.E.; MORRISON, J.C.; LOUCKS, C.J.; ALLNUTT, T.F.; RICKETTS, T.H.; KURA, Y.; LAMOREUX, J.F.; WETTENGEL, W.W.; HEDAO, P.; KASSEM, K.R. Terrestrial Ecoregions of the World: A New Map of Life on Earth. **BioScience**, 51, 11, p. 933-938, 2001.

PIMM, S. L.; JENKINS, C. N.; ABELL, R.; BROOKS, T. M.; GITTLEMAN, J. L.; JOPPA, L. N.; RAVEN, P. H.; ROBERTS, C.M.; SEXTON, J. O. The biodiversity of species and their rates of extinction, distribution, and protection. **Science**, 344, 6187, p. 1246752–1246752, 2014.

SAITER, F.Z.; BROWN, J.L.; THOMAS, W.W.; DE OLIVEIRA-FILHO, A.T.; CARNAVAL, A.C. Environmental correlates of floristic regions and plant turnover in the Atlantic Forest hotspot. **Journal of Biogeography**, 43, 12, p. 2322–2331, 2016.

SANTOS, A. M. C.; JONES, O. R.; QUICKE, D. L. J.; HORTAL, J. Assessing the reliability of biodiversity databases: identifying evenly inventoried island parasitoid faunas (Hymenoptera: Ichneumonoidea) worldwide. **Insect Conservation and Diversity**, **3**, 2, p. 72–82, 2010.

SIGRIST, M.S.; CARVALHO, C.J.B. Detection of areas of endemism on two spatial scales using Parsimony Analysis of Endemicity (PAE): the Neotropical region and the Atlantic Forest. **Biota Neotropica** 8, 4, p. 33-42, 2008.

SILVA, S. M.; MORAES-BARROS, N.; RIBAS, C. C.; FERRAND, N.; MORGANTE, J. S. Divide to conquer: a complex pattern of biodiversity depicted by vertebrate components in the Brazilian Atlantic Forest. **Biological Journal of the Linnean Society**, 107, 1, p. 39–55. 2012.

SIMMONS, N. B. Order Chiroptera. *In*: WILSON, D.E.; REEDER, D.M. (eds.). **Mammal species of the World: a taxonomic and geographic reference.** Third Edition, Volume 1, Johns Hopkins University Press, 2005, p. 312-529.

SIMON, L.M.; OLIVEIRA, G.; BARRETO, B.S.; NABOUT, J.C; RANGEL, T.F.L.V.B.; DINIZ-FILHO, J.A.F. Effects of global climate changes on geographical distribution patterns of economically important plant species in cerrado. **Revista Árvore**, 3, 2, p. 267-274, 2013.

SIMPSON, G. 2018. **CRAN Task View: Analysis of Ecological and Environmental Data**. Disponível em: https://cran.r-project.org/web/views/Environmetrics.html Acessado em: 30 abril 2020.

SOBRAL-SOUZA, T.; VANCINE, M. H.; RIBEIRO, M. C.; LIMA-RIBEIRO, M. S. Efficiency of protected areas in Amazon and Atlantic Forest conservation: A spatio-temporal view. **Acta Oecologica**, 87, p. 1–7, 2018.

SOCOLAR, J. B.; GILROY, J. J.; KUNIN, W. E.; EDWARDS, D. P. How Should Beta-Diversity Inform Biodiversity Conservation? **Trends in Ecology & Evolution**, 31, 1, p. 67–80, 2016.

SOININEN, J.; WANG, J.; HEINO, J. A meta-analysis of nestedness and turnover components of beta diversity across organisms and ecosystems. **Global Ecology and Biogeography**, 27, 1, p. 1-14, 2018.

STEVENS, R. D. Gradients of bat diversity in Atlantic Forest of South America: Environmental seasonality, sampling effort and spatial autocorrelation. **Biotropica**, 45, p. 764–770, 2013.

STEVENS, R. D.; LÓPEZ-GONZÁLEZ, C.; PRESLEY, S. J. Geographical ecology of Paraguayan bats: Spatial integration and metacommunity structure of interacting assemblages. **Journal of Animal Ecology**, 76, p. 1086–1093, 2007.

VARZINCZAK, L.H.; LIMA, C.S.; MOURA, M.O.; PASSOS, F.C. Relative influence of spatial over environmental and historical processes on the taxonomic and phylogenetic beta diversity of Neotropical phyllostomid bat assemblages. **Journal of Biogeography**, 45, p. 617–627, 2018.

VARZINCZAK, L.H.; MOURA, M.O.; LIMA, C.S.; PASSOS, F.C. How do bat, rodent, and marsupial communities respond to spatial and environmental gradients? Insights from a deconstruction of mammal beta diversity from the Atlantic Forest of South America. **Oecologia**, 189, 4, p. 851-861, 2019.

VELLEND, M.; BAETEN, L.; BECKER-SCARPITTA, A.; BOUCHER-LALONDE, V.;

MCCUNE, J. L.; MESSIER, J.; MYERS-SMITH I.H.; SAX, D.F. Plant Biodiversity Change Across Scales During the Anthropocene. **Annual Review of Plant Biology**, 68, 1, 563–586, 2017.

WILLIAMS, K.J.; FORD, A.; ROSAUER, D.F.; DE SILVA, N.; MITTERMEIER, R.A.; BRUCE, C.; LARSEN, F.W.; MARGULES, C. Forests of East Australia: The 35th Biodiversity Hotspot. *In*: ZACHOS, F.E., HABEL, J.C. (eds**) Biodiversity Hotspots: Distribution and Protection of Priority Conservation Areas**. Springer-Verlag, Berlin. 2011, p. 295-310.

WILLIG, M. R.; KAUFMAN, D. M.; STEVENS, R. D. Latitudinal gradients of biodiversity: Pattern, process, scale, and synthesis. **Annual Review of Ecology Evolution and Systematics**, 34, 273–309, 2003.

WRIGHT S. J. Tropical forests in changing environment. **Trends in Ecology & Evolution**, 20, p. 553–60, 2005.

3. CAPÍTULO 1

Thirty-six years of research on bats in the region of Londrina, Brazil: what have we learned?

Trinta e seis anos de pesquisas com morcegos na região de Londrina, norte do Paraná, Brasil: o que sabemos?

Carolina Blefari Batista[1]*; Isaac Passos de Lima[1]; Marcos Robalinho Lima[1]

[1] - Programa de Pós-Graduação em Ciências Biológicas; Departamento de Biologia Animal e Vegetal; Centro de Ciências Biológicas; Universidade Estadual de Londrina; 86051-970, Londrina, Brazil; Phone: (+55) 43 3371-4911

*- Corresponding Author: blefaricarol@gmail.com

Abstract

Providing reliable databases on biodiversity is important, as they are the raw material for complex studies in ecology, biogeography and conservation. The region of Londrina, Paraná state (Brazil), has had its bat fauna studied for over 36 years, by a group of researchers from the Laboratório de Ecologia de Mamíferos of the Universidade Estadual de Londrina. This generated an extensive published and unpublished literature (monographs, master's and PhD theses) on the diversity of bats in the region. We compiled and reviewed all of the bat studies carried out in the Londrina region and made a database with information on richness, distribution and sampling gaps. Our compilation resulted in 41 species, of which 29 occur within Protected Areas. Despite the long sampling time, we found that the region still has a lack of information on bat fauna for most of its forest remnants, especially in the northern region. In addiction, the forest fragment with the greatest number of sampling nights (Parque Estadual Mata dos Godoy) is undersampled. Thus, we present a reliable database that can serve as a basis for more complex studies and as a guide of where sampling effort should occur in future projects with bats in the region.

Keywords: Chiroptera, Paraná state, Brazil, diversity, sampling gaps.

Resumo

Construir e disponibilizar bancos de dados confiáveis sobre a biodiversidade é importante, pois eles são a matéria prima para estudos complexos em ecologia, biogeografia e conservação. A região de Londrina, Paraná, teve sua fauna de morcegos estudada ao longo de 36 anos, por um grupo de pesquisadores do Labortório de Ecologia de Mamíferos da Universidade Estadual de Londrina. O que gerou uma extensa literatura publicada e não publicada (monografias, dissertações e teses) sobre a diversidade de morcegos na região. Nós compilamos e revisamos todos os trabalhos com morcegos na região de Londrina e construímos um banco de dados com informações sobre riqueza, distribuição e lacunas de amostragens. Nossa compilação resultou em 41 espécies, das quais 29 ocorrem dentro de Unidades de Conservação. Descobrimos que apesar do longo tempo de amostragem, a região permanece com a maior parte de seus remanescentes florestais sem informações para a fauna de morcegos, principalmente na porção norte. O fragmento com maior número de noites de amostragem (Parque Estadual Mata dos Godoy) está subamostrado. Dessa forma, apresentamos um confiável banco de dados que pode servir de base para estudos mais complexos e orientar o direcionamento do esforço de amostragem em futuros projetos com morcegos na região.

Palavras-chave: Chiroptera, Paraná, Brasil, diversidade, lacunas de amostragem.

3.1. Introduction

Databases on the occurrence and abundance of species aim at compiling and making available taxonomic data that is scattered throughout the literature, museum collections and other non-published sources, such as monographs, dissertations and theses (Hortal *et al*., 2007). It is undeniable that the availability of biodiversity databases has greatly advanced and improved studies on ecological and biogeographical patterns (Santos *et al*., 2010). However, these online data bases (e.g. GBIF and SpeciesLink) are based on the digitalization of natural history collections of different museums, where a formal control process is nonexistent, and the amount of detail and quality of data is strongly depedent on the data supplier (Maldonado *et al*. 2015). Therefore, it is not uncommon to find species occurrence records with erroneous georeferencing or mistakes in their taxonomic identification, and it is recommended to verify the data with substantial taxonomic knowledge before applying biodiversity analysis.

Limitations on the accuracy and precision of the data (e.g., erronous georeferecing and taxonomic misidentification) may lead to two types of errors on species distribution (Hortal, 2008). Error 1 leads to false positive, or the attribution of a species to a site where it does not occur; Error 2 leads to false negative, or the omission of a species distribution on a site where it actually occurs. The above errors addresses issues in more complex ecological, biogeographic and conservation studies. For example, distribution or niche models use species occurrence and predictor variables of occurrence site to build their projections (i.e. Dobrovolski *et al.*, 2012; Aguiar *et al.*, 2016; Delgado-Jaramillo *et al.*, 2020; Batista et al., 2020). Further, knowledge on the biodiversity of forest remnants is crucial to choose new Priority Areas and to maintain already existing ones (i.e Sigrist and Carvalho, 2008; Campos; Lourenço-De-Moraes, 2017; third chapter). Consequently, databases should be developed by experts to guarantee information that is reliable, of good quality and systematized. The compilation of species occurrence records into local lists, with as much information as possible and revised, constitute the smallest unit of the most accessed global databases. That is why local lists are important to maintain the quality of the global databases and, therefore, of the more complex studies developed from them.

Bats rank second in mammal diversity, after rodents (Simmons, 2005). Due they are distributed worldwide, to have diversified life habits (living in caves, trees, tree hollows, and even human building, and which feed on fruits, nectar, insects and other invertebrates, small vertebrates and blood) (Kalka et al., 2008), and great dispersion capacity (Kalka et al., 2008), bats have been widely employed in ecological and biogeographic studies, such as species distribution models (Stevens et al., 2007; Stevens, 2013; López-González et al., 2015; Varzinczak et al., 2018; Varzinczak et al., 2019, Batista et al., 2020), which require good quality data both on taxonomic identification and georeferecing of species occurrences.

There are at present 182 bat species in Brazil (Nogueira et al., 2018) and, at least, 63 species occur in the state of Paraná (Passos et al., 2010; Garbino and Nogueira, 2017). Bat fauna in the region of Londrina, northen of Paraná, has been investigated since 1982 by a research group at the Laboratório de Ecologia de Mamíferos of the Universidade Estadual de Londrina being one of the most researched location for these taxa in the state of Paraná (Miretzki, 2003). These three decades of sampling efforts have had public financial investment (CAPES, CNPQ and Fundação Araucária) and personnel, which only further highlights the importance of retrieving this information and making it public. Therefore, in this study we compile and organize all available information on published and non-published data of bat species in the region of Londrina to provide a systematized and taxonomically verified database. In addition, the state of Paraná is in third place in the deforestation ranking of the Atlantic Forest (SOS Mata Atlântica, 2018), the north of Paraná being one of the most affected and fragmented regions. This makes it urgent to increase efforts for cataloging of new occurrences of species that may not have been recorded for the region yet because of the sampling effort. Therefore, we also detect and point out information gaps to direct where and how new inventories should be undertaken.

3.2. Methodology

3.2.1. Londrina region

The municipality of Londrina lies in the northern region of the state of Paraná, Brazil, with an area of approximately 1,650,809 km² (IBGE, 2010). Climate (Cfa) (Köppen, 1948) features humid subtropical, with hot summers, and rainfall throughout the year, decreasing in the winter. The region belongs to the Atlantic Forest biome within the Alto Paraná ecoregion, covered by Semi-deciduous Seasonal Forest. Mean yearly rainfall is 1,888 mm and mean yearly temperature lies at 21.6° C (IAPAR, 2019). Londrina's zoning directive (Prefeitura de Londrina, 2019) acknowledges 24 green areas in the municipality, some of which have been extensively sampled for bats since 1982: non-identified valleys; the banks of the Igapó Lake on the south-eastern segment of Londrina; Jardim Botânico de Londrina (23°21′57.60″S; 51°10′39.72″W) (~73 ha); the campus of the Universidade Estadual de Londrina (UEL) (23°19'19"S; 51°12'04"W) with its Horto Florestal (~10 ha). The sites are covered with secondary forest remnants, featuring native and exotic vegetation, inserted within the metropolitan region's urban matrix.

Several Legal Reserves within private farmland, with native and exotic secondary vegetation, have also been studied for bats. They comprise of Mata do Bule (~300 ha) (23°24′10.80″S; 51°20′13.20″W), Fazenda Regina (~6.2 ha) (23°11'1,70"S; 51° 7'39,70"W), Chácara Vitória (~1 ha) (23°22'48,52"S; 51°4'34,39"W), Fazenda Imbaúva (area unknown and without any geo-reference, in the district of Irerê - Reis et al., 1993) and Chácara Kanashiro (area unknown and without any geo-reference, between the municipality of Londrina and the district of Irerê – Reis et al., 1993). Further, Londrina has two Protected Areas (PAs) acknowledged by the Instituto Ambiental do Paraná (IAP), extensively sampled for bats. The Parque Municipal Arthur Thomas (PMAT) (23°20'39"S; 51°8'6"W) lies within the south-west urban matrix and features 85.47 ha of secondary forest, whilst the Parque Estadual Mata dos Godoy (PEMG) (23°26'53"S; 51°15'21"W), albeit with an area close to 680 ha, is contiguous with other forest fragments which together make up an area of ~ 2.800 ha. PEMG, within agricultural and stock-breeding culture areas, is one of the most important forest remnants in the northern region of the state of Paraná, Brazil (Figure 1).

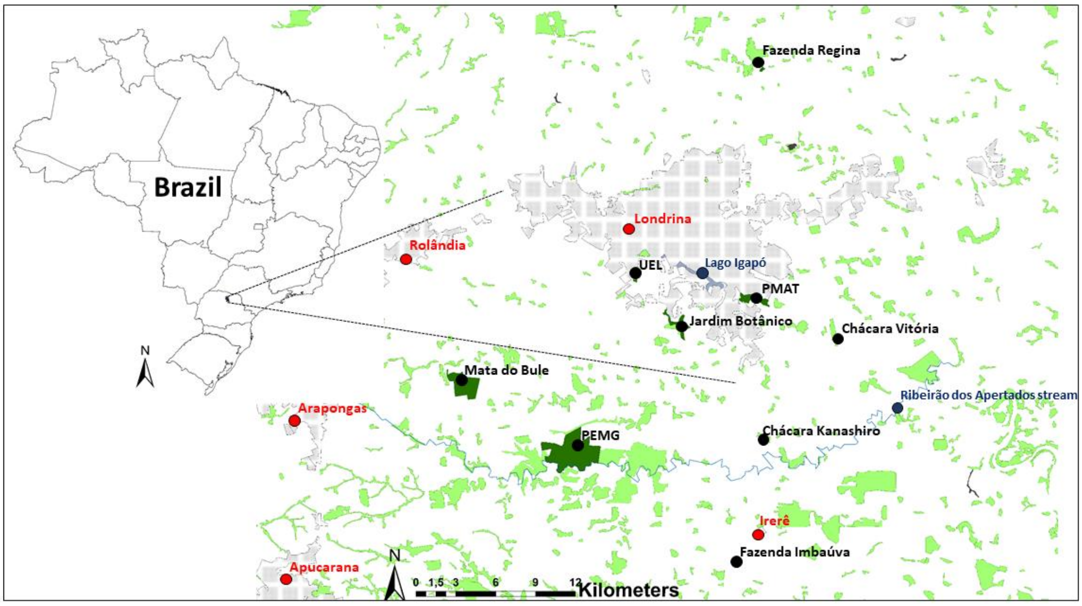


Figure 1. Londrina region, Paraná, Brazil. The black dots point to areas of the region that have already been sampled for bats since 1982. The two Protected Ares in the region: PMAT – Parque Municipal Arthur Thomas (23°20'39"S; 51°8'6"W); and PEMG – Parque Estadual Mata dos Godoy (23°26'53"S; 51°15'21"W). The metropolitan green areas: UEL – Campus da Universidade Estadual de Londrina (including Horto Florestal) (23°19’19”S; 51°12’04”W) and Jardim Botânico de Londrina (23°21′57.60″S; 51°10′39.72″W). The Mata do Bule (23°24′10.80″S; 51°20′13.20″W), Fazenda Regina (23°11'1,70"S; 51° 7'39,70"W), Fazenda Imbaúva (area unknown and without any geo-reference, in the district of Irerê - Reis et al., 1993), Chácara Kanashiro e Chácara Vitória, are Legal Reserves within private farmland. The location of Fazenda Imbaúva and the Chácara Kanashiro are in approximate locations, based on the map available in Reis et al., (1993), since the exact coordinates of these locations were not found.

3.2.2. Collection data

We listed the occurrences (species richness; presence) of bat species registered in Londrina between 1982 and 2018 throughout the scientific literature and non-published data. The latter were retrieved from field notes, monographs and dissertations at the Laboratório de Ecologia de Mamíferos of the Universidade Estadual de Londrina (Table 1 in pag. 87). The first step consisted of verifying all records and establishing filters for the exclusion of false occurrences. Exclusion criteria comprised lack of voucher specimen deposited in the Museu de Zoologia (MZUEL) or at the Laboratório de Ecologia de Mamíferos of the Universidade Estadual de Londrina; expected geographic distribution of species based on the literature; and the lack of precise site where the species was captured.

A Venn-Euler diagram was used to illustrate the occurrence of bat species in the region of Londrina. Species taxonomy followed updated and commented list of Brazilian bats (Nogueira et al., 2014). Conservation status of each species was based on international (IUCN, 2020), national (ICMBio/MMA 2018) and regional lists “Livro vermelho da fauna ameaçada no Estado do Paraná” (Margarido and Braga, 2004).

3.2.3. Sample gaps in the region of Londrina

Data were tabulated in our database (Table 1-3 in pag. 87). In this database we compiled information about the number of capture nights (the only common information among published and non-published data available for the sampling effort) and the environments where mist nets were installed in each sample site. Therefore, we evaluate whether sampling effort was heterogeniously distributed in the different environments within the forest fragments.

Using ArcGIS 10.5 from ESRI (ArcGIS trial), a 30 km² buffer from downtown Londrina was constructed. The distance was large enough to comprise all of the sampled forest fragments for bats in the region. Based on this vector layer, the area (ha) of all fragments located within a 30 km²-radius was added, and only for the fragments that had an exact georeferenced location (namely, PEMG, PMAT, Mata do Bule, Jardim Botânico, Horto Florestal in UEL and Fazenda Regina). This allowed us to calculate the percentage of sampled area for the 30 km²-radius. In the case of non-sampled fragments, we employed the ArcGis option for the classification of the vector layer according to certain characteristics. The variable ‘fragment size’ coupled with the use of six classes was selected. Non-sampled fragments were divided into: smaller than 30 ha; between 30 and 48 ha; between 48 and 70 ha; between 70 and 114 ha; between 144 and 196 ha; between 196 and 504 ha. This allowed us to locate and determine the number of fragments in each class.

3.3. Results

Forty-one bat species were listed, distributed into four families, nine subfamilies and 27 genera. Records were obtained from ten georeferenced sites and other green areas in the Londrina (non-identified valleys) and human building (sites without exact indication), in 577 sampling nights since 1982. All of the bat guilds (nectarivores, frugivores, insectivores, carnivores, omnivores, hematophages and piscivores) are present (Table 2 in pag. 90). We excluded only one record - *Uroderma bilobatum* - previously listed for the region of

Londrina, according the exclusion filter (lack of voucher specimen and expected geographic distribution of species based on the literature - Garbino and Nogueira, 2017).

The PEMG and PMAT harbor, respectively, 68.3% and 41.50% of the bat fauna in the region of Londrina. Seven out of the 12 species which were not recored in the two PAs (Figure 2) were listed only in the green areas of the metropolitan region; two species were registered on private farms and other two species in human building; there was no environmental information of locality indication of where *Eumops perotis* was captured in the metropolitan region of Londrina (Table 2 in pag. 90). Four species in our list had a certain degree threat, with *Diaemus youngii* classified as “critically endangered” (Margarido and Braga, 2004) *Diphylla ecaudata*, *Chrotopterus auritus* and *Chiroderma doriae* being listed as “vulnerable (Margarido and Braga, 2004); and *Myotis ruber* as “near threatened” (IUCN, 2020).

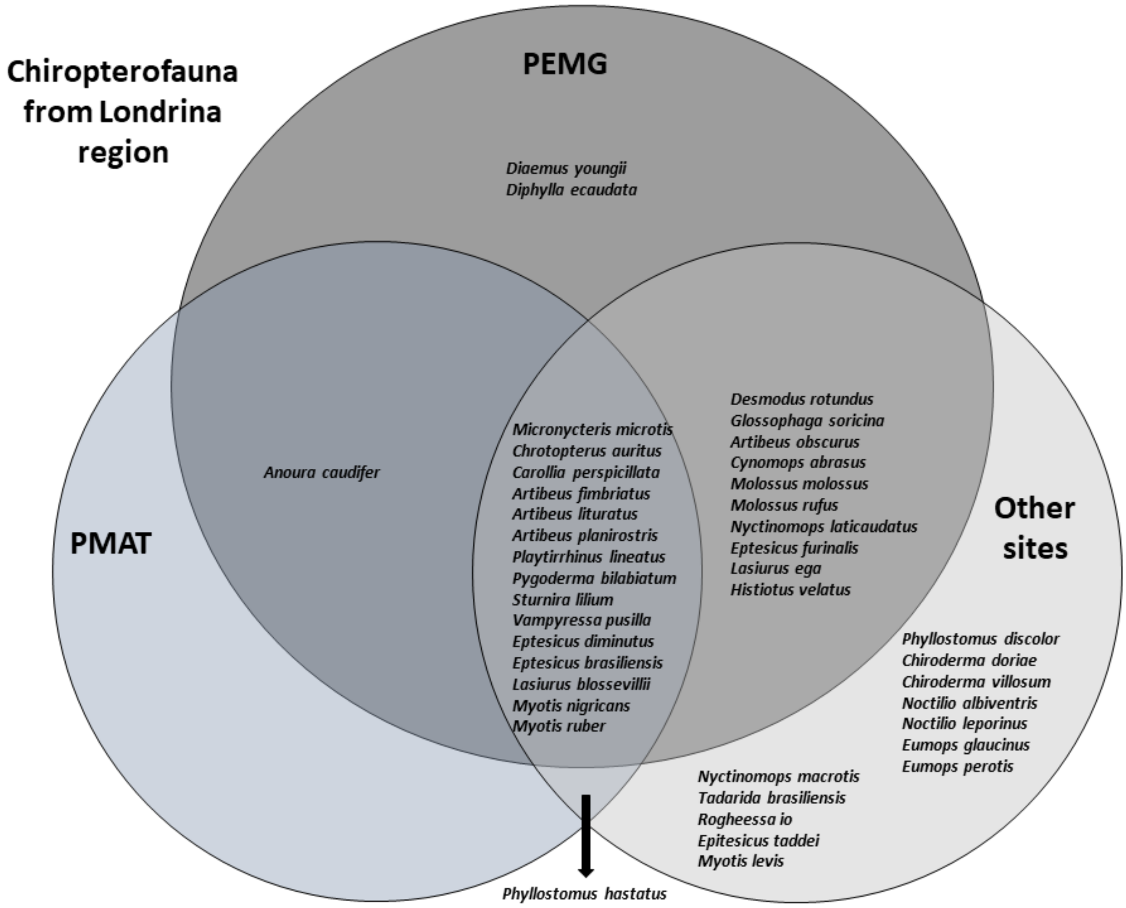


Figure 2. Venn-Euler diagram to illustrate occurrence of bat species in the region of Londrina, Paraná, Brazil. Two Protected Areas - Parque Estadual Mata dos Godoy (PEMG) and Parque Municipal Arthur Thomas (PMAT). “Other sites” indicate Legal Reserves (Mata do Bule, Fazenda Imbaúva, Chácara Kanashiro, Chácara Vitória and Fazenda Regina), the campus of Universidade Estadual de

Londrina (UEL) (including the Horto Florestal); the Jardim Botânico; banks of the Igapó Lake; other green areas in the municipality (non-identified valleys) and human building (sites without exact indication). The arrow indicates where *Phyllostomus hastatus* is in the diagram, within the "PMAT" and "Other sites" set.

We managed to retrieve information on the environment of captured sites for five forest fragments in the region of Londrina: PEMG, PMAT, UEL, Jardim Botânico and Mata do Bule. In the case of PEMG, data are not available in the published literature and they were provided by researchers from the Laboratório de Ecologia de Mamíferos of the Universidade Estadual de Londrina. Bat mist-nets in the park were placed along two trails (Trilha das Perobas and Trilha dos Catetos) during 238 sampling nights. PMAT was sampled for 106 nights, while the UEL campus was sampled for 133 nights. Mist-nets in both areas were distributed throughout the area. In the Jardim Botânico, captures were undertaken for 16 nights in several places, but was restricted to the eastern region where the area is open to visitors. Mist-nets were installed in the Mata do Bule at random, in all regions of the forest fragment (north, south, east and west), with a total of 14 sampling nights. Table 3 (in pag. 100) gives all available data regarding sampling effort and locality of mist-nests.

Spatial analysis revealed that less than 4% of forest fragments in the region of Londrina, within a 30 km radius, were sampled for bats. Moreover, most of the sampling (with the exception of Fazenda Regina) took place in southern part of the region of Londrina. There are seven fragments with an area between 196 and 504 ha, of which five are greater than 300 ha; nine fragments between 196 and 114 ha; 21 fragments between 114 and 70 ha; 27 fragments between 70 and 48 ha; 37 between 48 and 30 ha; and several fragments with less than 30 ha. All of them have yet to be sampled for bats (Figure 3A).

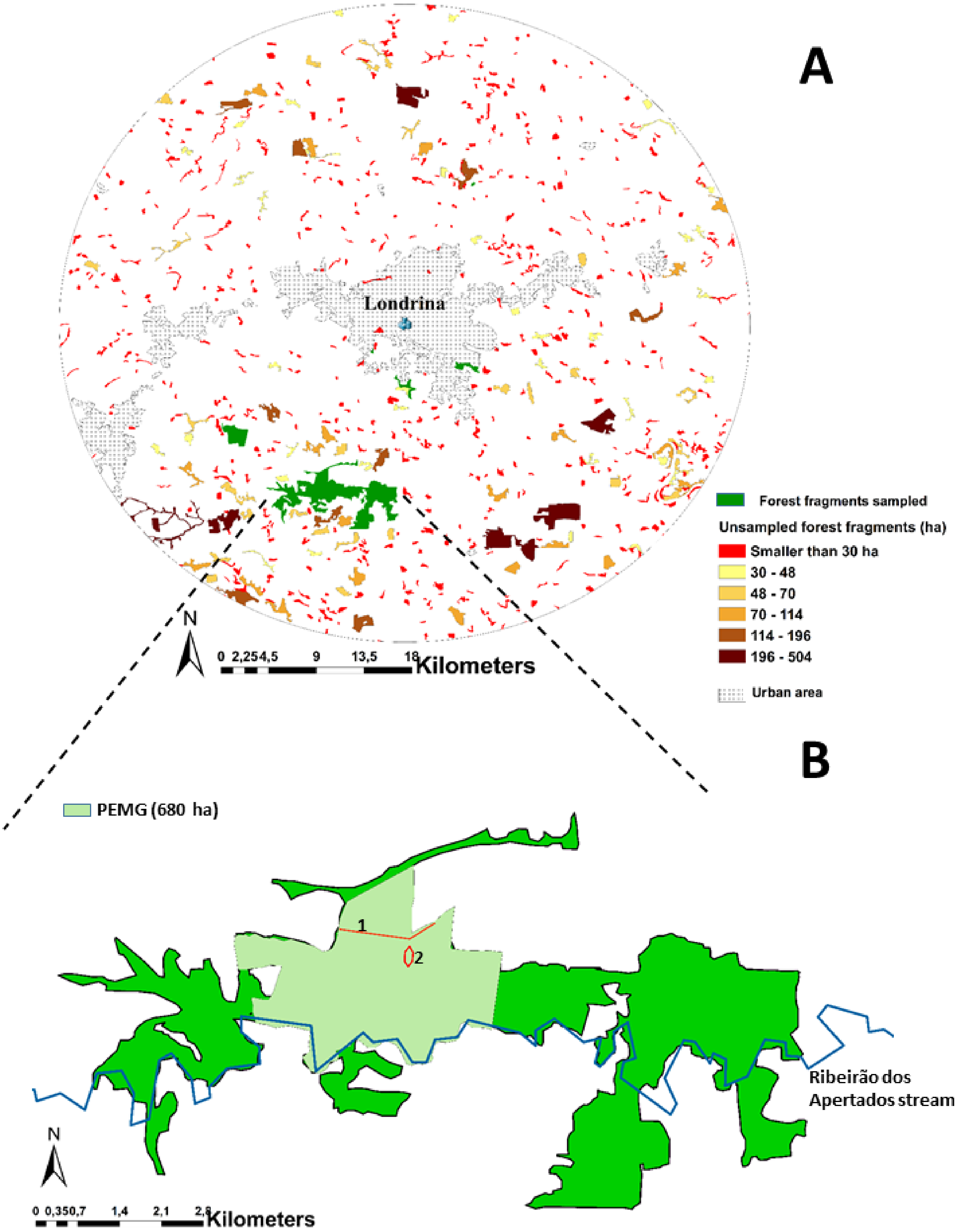


Figure 3. A) The 30 km² buffer from downtown Londrina, Paraná, Brazil. Green forest fragments are the areas that have already been sampled for bats. Unsampled fragments are classified in different colors depending on the size of the area in hectares: smaller than 30 ha; between 30 and 48 ha; between 48 and 70 ha; between 70 and 114 ha; between 144 and 196 ha; between 196 and 504 ha. **B)**

Highlights the largest forest fragment in the region of Londrina (~ 2000 ha), where the Parque Estadual Mata dos Godoy (PEMG) (23°26'53"S; 51°15'21"W) (which has 680 ha) is located. The figure also indicates the Ribeirão dos Apertados stream and the two visitor's track where bats were captured since 1982: Trilha dos Catetos (1) and Trilha das Perobas (2).

3.4. Discussion

Our review demonstrated that the region of Londrina has at least 65% of the bat fauna found in the state of Paraná (Passos et al., 2010; Garbino and Nogueira, 2017), and 43% of the species found in the Atlantic Forest (Muylaert et al., 2017). However, most of the Londrina region has never been inventoried and the region may have larger species richness than currently registered. *Uroderma bilobatum* was not included, since no voucher specimen has been deposited in the MZUEL or in the Laboratório de Ecologia de Mamíferos of the Universidade Estadual de Londrina. Exclusion of *U. bilobatum* was also recomended by Garbino and Nogueira (2017) on the basis of the species' natural history and the lack of voucher specimens deposited in public records. Therefore, the occurrence of this species should be excluted from reports of bat fauna for the state of Paraná. *Eumops perotis* should also be excluded due to the criteria used in this study (no voucher specimen has been deposited in the Zoological museums of the region). However, see Suckow et al. (2010) - the source for this species' registration for Londrina – and Figure 4. Briefly, the specimen was captured and forwarded to the Laboratório de Ecologia de Mamíferos of the Universidade Estadual de Londrina on August 3, 2004 by an unknown person on the recommendation of the health secretary of Londrina (Lima, I. P. personal communication).

The metropolitan green areas and Legal Reserves (rural forest areas) are relevant sites to maintain bat diversity in the Londrina region. In fact, when they were analyzed together, they harbored 95% of the bat species. The two PAs (PEMG and PMAT) are sites with high richness and a safe haven for all species, including threaten species. The PEMG is the sole occurrence site for two threatened hematophageous species, *D. ecaudata* and *D. younggii*. However, our results have shown that despite the great sampling effort in the region, there are still many sampling gaps. The region's biggest forest fragment comprises 2000ha, but samplings are limited to PEMG, which has an extention of only 680 ha within this 2000 ha forest fragment (Figure 3B). PEMG is one of the main forest remnants in the state of Paraná and one of the main genetic forest reserves in south Brazil (IAP, 2015), with the presence of different micro-habitats (Willrich et al., 2019). In spite of the great number of sampling nights (238) in the area, the sites where mist-nets were installed are mainly in the visitors tracks located in the northern part of the park (Figure 3B). The southern region on the banks of the Ribeirão dos Apertados stream has not been systematically sampled. There were only two sampling nights with zero specimen deposited in collections and without any field entries (Lima, I. P. personal communication). The region lies along an elevated gradient associated with changes in vegetation structure (Willrich et al., 2019), which with the water body provides a different set resources when compared to the northern part of the PEMG. For example, resources for *Noctilio leporinus*, a piscivore bat species, which has never been captured in the park. The above suggests that there are probably more bat species in the park area which have never been registered.

Smaller and and unprotected fragments, including metropolitan green areas, can also be important for the maintenance of bat diversity in the region of Londrina. However, these areas have low or no sampling, which suggests that the Londrina region may actually have a higher richness of bat species richness. A good example is the Mata do Bule Legal Reserve. In only 14 sampling nights, a total of nine species were recored, including the near threatened species *M. ruber* (Solaris, 2019). Further, 96% of the area covered by forest fragments have never been sampled, while the remaning 4% has an uneven distribution of sampling nights. For example, only one forest fragment (Fazenda Regina) has been sampled in the northern region of Londrina; all the other forest fragments lie in the southwestern region of Londrina. Moreover, the southeastern region contains three of the five largest fragments (over-300ha) in a 30km radius that have never been sampled (Figure 3A), showing the huge sampling gap for the region of Londrina.

There is a predominance of data gaps in biodiversity independent of taxa, and because acquisition of biodiversity data is based on local taxonomic surveys, these gaps accumulates at increasing scales (Hortal et al., 2007). A recent review on species distribution of vertebrates, arthropods and angiosperms in Brazil showed that the greatest sampling effort is concentrated in easily reached places, such as PAs and forest fragments close to roadways (Oliveira et al., 2017). Further complicating matters is the fact that even the current knowledge on biodiversity within PAs is still scanty, with less than 1% of the area being sampled for vertebrates, arthropods and angiospers in Brazil (Oliveira et al. 2017).

In the case of bats, there is still an additional issue with geographic sampling gaps. It is very common for bat inventories to be carried out using mist-nets, which may limit the detectability of bat families that are less prone to be sampled by this method, such as

Molossidae, Embalonuridae and Vespertilioniae (Simmons and Voss 1998, Carvalho et al., 2013). For instance, there are six insectivore species (*Eumops glaucinus*, *Eumops perotis*, *Nyctinomops macrotis*, *Tadarida brasiliensis*, *Epitesicus taddei*, *Rogheessa io* and *Myotis levis*), which have not been captured within the PAs of the region of Londrina. Lack of precision on the localities where these species were captured only allows us to assert that these species were captured within the metropolitan area. Urban areas usually present an abundance of insects that can be easily caught (insects flying around illuminated objects) and roosting areas (human buildings), which attracts insectivore bats (Pacheco et al., 2010). Moreover, it is easy to capture insectivorous bats in urban environment by actively searching for day roosting areas and/or placing mist-nets close to their exit. It is highly probable that the absence of occurrence records for these species within PAs and in the legal reserves of the region to be a type 2 Error - the false absence of species in places where they may actually occur.

Bat capture undertaken merely by mist-nets in forest fragments may increase type 2 error for insectivore bats of the families Molossidae, Vespertilionidae and Embalonuridae. Bats from these families usually fly very high and have a more efficient eco-localization system, making their capture with mist-nets a difficult task (Nogueira et al., 1999; Nogueira et al., 2008). This sample bias can lead to information gaps, for example, six species of insectivorous bats on our list (*Cynomops abrasus*, *Eptesicus diminutus*, *Eptesicus taddei*, *Rogheessa io*, *Histiotus velatus* and *Myotis ruber*) of the Molossidae and Vespertilionidae families, are categorized as "data deficient" by at least one of the lists that assessed the degree of threat to species (Table 2 in pag. 90).Therefore, it is imperative to sample bats in the Londrina region with alternative and complementary methods (Bergallo et al., 2003) because this will surely increase the number of species recorded for the area. Methods include searching for roosting sites during the day (Simmons and Voss, 1998), the construction of artificial roost to attract bats (bat houses) (Tuttle and Donna, 1993), the monitoring of eco-localization callings to allow the identification of species by ultrasound (Arias-Aguilar et al., 2018), and the installation of canopy mist-nets (Carvalho and Fabián, 2011).

Our results are based on reviewing the scientific literature and careful compilation of several small monitoring projects in Londrina since 1982, which allowed us to determine the bat species that occurs in the area and the sampling gaps. Besides being a reliable dataset, our review also provides the basis for more complex ecological studies, as well as guidance to where future bat surveys should be conduced. Lastly, we have shown the conservation relevance of several forest fragments of different types (e.g., urban green areas, Legal Reserves and Protected Areas) in the landscape should be underscored to maintain bat diversity in the region of Londrina.

Figure 4. Specimen of *Eumops perotis* received by the Laboratório de Ecologia de Mamíferos of the Universidade Estadual de Londrina on August 03, 2004 by an unidentified person. The animal was alive, was identified and released. This record is published at Suckow et al. (2010). Picture by Isaac Passos de Lima.

Acknowledgements

The authors would like to thank the Programa de Pós Graduação da Universidade Estadual de Londrina for logistic support. We would also like to thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) that financed part of the study (Finance code 001) and Fundação Araucária for providing a scholarship to CB Batista (Edital 20/2015). We also want to thank Juliana Felix for providing her field notebook with data that was used in this study, and to Dr. Luíz dos Anjos, Dra. Thaís Pires Miranda and Dr. Efraim Rodrigues, for their suggestions in an earlier version of the manuscript. Finally, a special thanks to Professor Dr. Nelio Roberto dos Reis, for his great contribution in bat research along his academic trajectory.

References

AGUIAR, L. M. S.; BERNARD, E.; RIBEIRO, V.; MACHADO, R. B.; JONES, G. 2016. Should I stay or should I go? Climate change effects on the future of Neotropical savannah bats. *Global Ecology and Conservation*, 5: 22–33.

ARIAS-AGUILAR, A.; HINTZE, F.; AGUIAR, L. M. S.; RUFRAY, V.; BERNARD, E.; PEREIRA, M. J. R. 2018. Who's calling? Acoustic identification of Brazilian bats. *Mammal Research*, **63**(3): 231–253.

BATISTA, C. B., LIMA, I. P., LIMA, M. R. 2020. Beta diversity patterns of bats in the Atlantic Forest: How does the scale of analysis affect the importance of spatial and environmental factors? *Journal of Biogeography*, 00: 1-10.

BATISTA, C. B.; PEREIRA, A. D.; LIMA, I. P.; REIS, N. R. 2018. Morcegos (Mammalia: Chiroptera) de dois fragmentos florestais na região de Londrina, norte do Paraná, Brasil. *Boletim da Sociedade Brasileira de Mastozoologia*, 82: 60–67.

BERGALLO, H.G.; ESBÉRARD, C.E.L.; MELLO, M.A.R.; LINS, V.; MANGOLIN, R.; MELO, G.G.S.; BAPTISTA, M. 2003. Bat species richness in Atlantic Forest: what is the minimum sampling effort? *Biotropica,* **35**(2): 278–288.

CAMPOS, F.S.; LOURENÇO-DE-MORAES, R. 2017. Anurans from the mountain chain Serra do Mar: a critical area for amphibian conservation in the Atlantic Forest, Brazil. *Herpetology Notes*, 10: 547–560.

CARVALHO, F.; FABIÁN, M. E. 2011. Método de elevação de redes de neblina em dosséis florestais para amostragem de morcegos. *Chiroptera Neotropical*, **17**(1): 797-802.

CARVALHO, F.; FABIÁN, M. E.; MENEGHETI, J. O. 2013. Vertical structure of an assemblage of bats (Mammalia: Chiroptera) in a fragment of Atlantic Forest in Southern Brazil. *Zoologia*, **3** (5): 491–498.

DELGADO-JARAMILLO, M.; AGUIAR, L. M. S.; MACHADO, R. B.; BERNARD, E. 2020. Assessing the distribution of a species-rich group in a continental-sized megadiverse country: Bats in Brazil. *Diversity and Distributions,* 00:1–12.

DOBROVOLSKI, R.; MELO, A. S.; CASSEMIRO, F. A. S.; DINIZ-FILHO, J. A. F. 2012. Climatic history and dispersal ability explain the relative importance of turnover and nestedness components of beta diversity. *Global Ecology and Biogeography* **21**(2):1–7

FÉLIX, J. S.; REIS, N.R.; LIMA, I.P.; COSTA, E.F.; PERACCHI, A.L. 2001. Is the area of the Arthur Thomas Park, with its 82,72 ha, sufficient to maintain viable chiropteran populations? *Chiroptera Neotropical*, **7**(1,2): 129–133.

FREGONEZI, M. N. 2012. *Gradiente borda/interior na comunidade de morcegos (Chiroptera: Mammalia) de um fragmento de Mata Atlântica do norte do Paraná, sul do Brasil*. Londrina, Paraná. Master Thesis. Programa de Pós Graduação em Ciências Biológicas da Universidade Estadual de Londrina, p. 43.

GARBINO, G.S.T.; NOGUEIRA, M.R. 2017. On the mammals collected by Friedrich Sellow in Brazil and Uruguay (1814-1831), with special reference to the types and their provenance. *Zootaxa (Online)*, 4221: 172–190.

HORTAL, J. 2008. Uncertainty and the measurement of terrestrial biodiversity gradients. *Journal of Biogeography*, **35**(8): 1335–1336.

HORTAL, J.; LOBO, J. M.; JIMÉNEZ-VALVERDE, A. 2007. Limitations of Biodiversity Databases: Case Study on Seed-Plant Diversity in Tenerife, Canary Islands. *Conservation Biology*, **21**(3): 853–863.

IAP. Instituto Ambiental do Paraná. 2015. Plano de Manejo do Parque Estadual Mata dos Godoy. Available at: http://www.iap.pr.gov.br/pagina-1218.html Accessed on: 10 April, 2020.

IAPAR. Instituto Agronômico do Paraná. 2019. Available at: http://www.iapar.br/pagina-2245.html. Accessed on: 20 June, 2019.

IBGE. Instututo Brasileiro de Geografia e Estatística. 2010. Censo 2010. Available at: https://cidades.ibge.gov.br/brasil/pr/londrina/panorama. Accessed on: 20 June, 2019.

ICMBio/MMA. 2018. Livro Vermelho da Fauna Brasileira Ameaçada de Extinção: Volume I / -- 1. ed. -- Brasília, DF:. 492 p.

IUCN. 2020. The IUCN Red List of Threatened Species. Version 2020-1. Available at: http://www.iucnredlist.org/. Accessed on: 06 june, 2020.

KALKA, M.B.; SMITH, A.R.; KALKO, E.K. 2008. Bats limit arthropods and herbivory in a tropical forest. *Science*, **320**(5872): 71.2008.

KÖPPEN, W. 1948. *Climatologia: con un studio de los climas de la tierra*. Mexico, Fondo de cutura econômica, 478 p.

LIMA, I.P. 1994. *Aspectos ecológicos dos quirópteros do "campus" da Universidade Estadual de Londrina*. Londrina, Paraná. Monography. Universidade Estadual de Londrina, p. 32.

LÓPEZ-GONZÁLEZ, C.; PRESLEY, S. J.; LOZANO, A.; STEVENS, R. D.; HIGGINS, C. L. 2015. Ecological biogeography of Mexican bats: The relative contributions of habitat heterogeneity, beta diversity, and environmental gradients to species richness and composition patterns. *Ecography*, 38: 261–272.

MALDONADO, C., MOLINA, C. I., ZIZKA, A., PERSSON, C., TAYLOR, C. M., ALBÁN, J., CHILQUILLO, E.; RONSTED, N.; ANTONELLI, A. 2015. Estimating species diversity and distribution in the era of Big Data: to what extent can we trust public databases? *Global Ecology and Biogeography*, **24**(8), 973–984.

MARGARIDO, T.C.C.; BRAGA, F.G. 2004. Mamíferos. *In*: S. B., MIKICH; R. S., BÉRNILS (eds.). *Livro vermelho da fauna ameaçada no Estado do Paraná*. Curitiba, Instituto Ambiental do Paraná, p. 27–142.

MIRETZKI, M. 2003. Morcegos do Estado do Paraná, Brasil (Mammalia, Chiroptera): riqueza de espécies, distribuição e síntese do conhecimento atual. *Papéis Avulsos de Zoologia,* **43** (6): 101–138.

MULLER, M.F.; REIS, N.R. 1992. Partição de recursos alimentares entre quatro espécies de morcegos frugívoros (Chiroptera, Phyllostomidae). *Revista Brasileira de Zoologia*, **9** (3/4): 345–355.

MUYLAERT, R. D. L.; STEVENS, R. D.; ESBÉRARD, C. E.; MELLO, M. A.;

GARBINO, G. S.; VARZINCZAK, L. H.; FARIA, D.; WEBER, M. M.; ROGERI, P. K.; REGOLIN, A. L.; OLIVEIRA, H. F. M.; COSTA, L. M.; BARROS, M. A. S.; SABINO-SANTOS JR., G.; MARAIS, M. A. C.; KAVAGUTTI, V. S.; PASSOS, F. C.; MARJAKANGAS, E.; MAIA, F. G. M.; RIBEIRO, M. C.; GALETTI, M. 2017. Atlantic bats: A data set of bat communities from the Atlantic Forests of South America. *Ecology*, **98**(12), 3227–3227.

NOGUEIRA, M.R.; LIMA, I.P.; MORATELLI, R.; TAVARES, V.C.; GREGORIN, R.; PERACCHI. A.L. 2014. Checklist of Brazilian bats, with comments on original records. *Check List*, **10** (4), 808–821.

NOGUEIRA M.R.; LIMA, I.P.; GARBINO, G.S.T.; MORATELLI, R.; TAVARES, V.C.; GREGORIN, R.; PERACCHI. A.L. 2018. Updated checklist of Brazilian bats: version 2018.1. Comitê da Lista de Morcegos do Brasil—CLMB. Sociedade Brasileira para o Estudo de Quirópteros (Sbeq). Available at: http://www.sbeq.net/updatelist Accessed on: 20 June, 2019.

NOGUEIRA, M. R.; POL, A.; MONTEIRO, L. R.; PERACCHI, A.L. 2008. First record of Miller’s mastiff bat, *Molossus pretiosus* (Mammalia: Chiroptera), from the Brazilian Caatinga. *Chiroptera Neotropical*, **14** (1): 346–353.

NOGUEIRA, M. R.; POL, A.; PERACCHI, A.L. 1999. New records of bats from Brazil with a list of additional species for the chiropteran fauna of the state of Acre, western Amazon basin. *Mammalia*, **63** (3): 363–368.

OLIVEIRA, U.; SOARES-FILHO, B. S.; PAGLIA, A. P.; BRESCOVIT, A. D.; CARVALHO, C. J. B.; SILVA, D. P.; SANTOS, A. J. 2017. Biodiversity conservation gaps in the Brazilian protected areas. *Scientific Reports*, 7: 9141.

PACHECO, S.M.; SODRÉ, M.; GAMA, A.R.; BREDT, A.; CAVALLINI-SANCHES, E.M.; MARQUES, R.V.; GUIMARÃES, M.M.; BIANCONI, G. 2010. Morcegos Urbanos: Status do conhecimento e plano de ação para a conservação no Brasil. *Chiroptera* Neotropical, **16**(1): 629–647.

PASSOS, F.C.; MIRANDA, J.M.D.; BERNARDI, I.P.; KAKU-OLIVEIRA, N.Y.; MUNSTER, L.C. 2010. Morcegos da Região Sul do Brasil: análise comparativa da riqueza de espécies, novos registros e atualizações nomenclaturais (Mammalia, Chiroptera). *Iheringia*, **100** (1), 25–34.

Prefeitura de Londrina. 2019. Sistema de áreas verdes. Available at: https://www.londrina.pr.gov.br/index.php?option=com_content&view=article&id=228&Itemid=184 Accessed on: 20 June, 2019.

REIS, N.R.; GALLO, P.H.; PERACCHI, A.L.; LIMA, I.P.; FREGONEZI, M.N. 2012a. Sensitivity of populations of bats (Mammalia: Chiroptera) in relation to human development in northern Paraná, southern Brazil. *Brazilian Journal of Biology*, **72**(3), 511–518.

REIS, N.R.; FREGONEZI, M.N.; PERACCHI, A.L.; ROSSANEIS, B.K. 2012b. Metapopulation in bats of Southern Brazil. *Brazilian Journal of Biology*, **72**(3), 605-609.

REIS, N. R.; LIMA, I.P.; PERACCHI, A.L. 2006. Morcegos (Chiroptera) da área urbana de Londrina, Paraná, Brasil. *Revista Brasileira de Zoologia*, **19**(3), 739–746.

REIS, N.R.; MULLER, M.F. 1995. Bat Diversity of forest and open areas in a subtropical region of South Brazil. *Ecologia Austral*, 5: 31-36.

REIS, N.R.; PERACCHI, A.L.; ONUKI, M.K. 1993. Quirópteros de Londrina, Paraná, Brasil (Mammalia, Chiroptera). *Revista Brasileira de Zoologia*, **10**(3), 371–381.

REIS, N.R.; PERACCHI, A.L.; SEKIAMA, M.L.; LIMA, I.P. 2000. Diversidade de morcegos (Chiroptera, Mammalia) em fragmentos florestais no estado do Paraná, Brasil. *Revista Brasileira de Zoologia*, **17**(3), 697–704.

SANTOS, A. M. C.; JONES, O. R.; QUICKE, D. L. J.; HORTAL, J. 2010. Assessing the reliability of biodiversity databases: identifying evenly inventoried island parasitoid faunas (Hymenoptera: Ichneumonoidea) worldwide. *Insect Conservation and Diversity,* **3**(2): 72–82.

SEKIAMA, M. L. 1992. *Estrutura de comunidade de quiropteros na região de Londrina, PR*. Monography. Londrina, Paraná. Universidade Estadual de Londrina, Londrina/PR.

SEKIAMA, M. L. 1996. *Estrutura de comunidade de quirópteros (Mammalia; Chiroptera) no Parque Estadual Mata dos Godoy, Londrina - PR*. Curitiba, Paraná. Master Thesis, Universidade Federal do Paraná, p.90.

SIMMONS, N. B. 2005. Order Chiroptera. *In*: D. E. WILSON; D. M REEDER (eds.). *Mammal species of the World: a taxonomic and geographic reference*. Third Edition, Volume 1, Johns Hopkins University Press. p. 312–529.

SIMMONS, N.B.; VOSS, R.S. 1998. The Mammals of Paracou, French Guiana: a Neotropical lowland rainforest fauna. Part 1. Bats. *Bulletin of the American Museum of Natural History*, 237: 1–219.

SIGRIST, M.S.; CARVALHO, C.J.B. 2008. Detection of areas of endemism on two spatial scales using Parsimony Analysis of Endemicity (PAE): the Neotropical region and the Atlantic Forest. *Biota Neotropica* **8**(4):33–42.

SOLARI, S. 2019. *Myotis ruber*. The IUCN Red List of Threatened Species 2019: e.T14197A22062092. Available at: https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T14197A22062092.en. Accessed on: 19 April, 2020.

S.O.S Mata Atlântica. 2018. Relatório Anual. Available at: www.sosma.org.br Accessed on: 06 June, 2020.

STEVENS, R. D. 2013. Gradients of bat diversity in Atlantic Forest of South America: Environmental seasonality, sampling effort and spatial autocorrelation. *Biotropica*, 45: 764–770.

STEVENS, R. D.; LÓPEZ-GONZÁLEZ, C.; PRESLEY, S. J. 2007. Geographical ecology of Paraguayan bats: Spatial integration and metacommunity structure of interacting assemblages. *Journal of Animal Ecology*, 76: 1086–1093.

SUCKOW, U.M.S.; BIANCONI, G.V.; PAROLIN, L.C.; LIMA, I.P. 2010. First occurrences of the greater bonneted *Eumops perotis* (Molossidae) in the State of Paraná and synthesis of the known records for Brazil. *Biota Neotropical*, **10**(3): 453–456.

TUTTLE, M. D.; DONNA, L. H. 1993. *Bat House Builder's Handbook*. Austin, University of Texas Press. 35 p.

VARZINCZAK, L.H.; LIMA, C.S.; MOURA, M.O.; PASSOS, F.C. 2018. Relative influence of spatial over environmental and historical processes on the taxonomic and phylogenetic beta diversity of Neotropical phyllostomid bat assemblages. *Journal of Biogeography*, 45: 617–627.

VARZINCZAK, L.H.; MOURA, M.O.; LIMA, C.S.; PASSOS, F.C. 2019. How do bat, rodent, and marsupial communities respond to spatial and environmental gradients? Insights from a deconstruction of mammal beta diversity from the Atlantic Forest of South America. *Oecologia*, **189**(4): 851–861.

WILLRICH, G.; LIMA, M.R.L.; ANJOS, L. 2019. The role of environmental heterogeneity for the maintenance of distinct bird communities in fragmented forests. *EMU – Austral Ornithology*: 1–10.

4. CAPÍTULO 2

Beta diversity patterns of bats in the Atlantic Forest: How does the scale of analysis affect the importance of spatial and environmental factors?

Short running title: Beta diversity of bats in the Atlantic Forest

Carolina Blefari Batista[1]*; Isaac Passos de Lima[1]; Marcos Robalinho Lima[1]

[1] - Programa de Pós-Graduação em Ciências Biológicas; Departamento de Biologia Animal e Vegetal; Centro de Ciências Biológicas; Universidade Estadual de Londrina; 86051-970, Londrina, Brazil; Phone: (+55) 43 3371-4911

*- Corresponding Author: blefaricarol@gmail.com

ACKNOWLEDGEMENTS

The authors would like to thank Programa de Pós Graduação da Universidade Estadual de Londrina for logistic support. We would also like to thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) that financed part of the study (Finance code 001) and Fundação Araucária for providing a scholarship to CB Batista (Edital 20/2015). The authors would also like to thank the Dr. Luíz dos Anjos, Dra. Thaís Pires Miranda and Dr. Efraim Rodrigues, for their suggestions in an earlier version of the manuscript.

ABSTRACT

Aim

Environmental and spatial factors are broadly recognized as important predictors of beta diversity patterns. However, the scale at which beta diversity patterns are evaluated will affect the outcoming results. For example, studies at larger scales will usually find spatial processes as the main predictor of beta diversity patterns. In this study we evaluate how beta diversity patterns change when analyses are conducted at different scales by reducing the scale of analysis in a hierarchical manner.

Taxon

Chiroptera.

Location

Atlantic Forest biome.

Methods

Information on the occurrence of 59 bat species were obtained from the Atlantic Bats and Species Link database. We partitioned beta diversity into its two components (nestedness and turnover) and calculated these indexes hierarchically: the biome in its entirety (all ecoregions); between larger regions (north, central and south); and between ecoregions within each region. We performed a Generalized Dissimilarity Model (GDM) to identify and predict the turnover of bat species in the Atlantic Forest based on geo-climatic predictors. We obtained 19 geo-climatic data from AMBDATA, an environmental dataset based on different data sources commonly used in species distribution modeling.

Results

We found that turnover was the main component influencing a latitudinal gradient when the biome was analysed in its entirety. However, when the scale of the analysis was reduced, we found that species loss (nestdeness component) had a large effect in determining beta diversity dissimilarity. We also found that nestedness was the main pattern explaining beta diversity dissimilarity along a longitudinal gradient.

Main conclusions

Beta diversity patterns changed with the scale of analysis, which indicates that bat species composition does not follow the same pattern throughout the Atlantic Forest. This corroborates the importance of analysing beta diversity patterns at different scales in order to understand how environmental dissimilarity across geographic space can influence species distribution patterns.

Keywords: biogeography, Chiroptera, tropical forest, species dissimilarity, ecological predictors**,** ecoregions.

4.1. INTRODUCTION

Identifying patterns of species distribution and the potential factors involved in the shaping of biodiversity are central for the understanding of the evolutionary and macroecological processes influencing the structuring of communities (Leigh, O'Dea, & Vermeij, 2014). For example, by exploring the way in which the spatial divergence of taxa is associated with ecological and climatic gradients, allows the identification of potential filters (e.g., dispersal and environmental filters) involved in the shaping of biodiversity (Dobrovolski, Melo, Cassemiro, & Diniz-Filho, 2012; Gianuca, Declerck, Lemmens, & De Meester, 2017). However, the scale at which biodiversity is considered will influence the perception of species distribution patterns and their drivers (McGill, Dornelas, Gotelli, & Magurran, 2015). If the analysis is limited to measuring only local diversity (alpha diversity) without a regional analysis, inferences will be limited to identifying sites with higher biological diversity and at best the environmental and climatic factors associated with species richness gradients (Stevens & Willig, 2002; Dobrovolski et al., 2012). Conversely, comparing inter-site differences in species composition (beta diversity) at larger scales, allows for the evaluation of the effect of ecological gradients on biodiversity patterns, which provides a better understanding of the potential mechanisms involved in the distribution of species at a larger scale.

The regional component of biodiversity can be included by performing a beta diversity analysis, which concerns variation in species composition among different sites (Whittaker, 1960; Chao & Ricota, 2019). Beta diversity can be explained by two distinct components: nestedness and species turnover. Nestedness is characterized by the loss or gain of species, while species turnover is the replacement of species along an environmental gradient owing to historical processes (Baselga & Orme, 2012; Socolar, Gilroy, Kunin, & Edwards, 2016; Coelho, Carneiro, Branco, Borges, & Fernandes, 2018). Environmental dissimilarity should be greater for spatially large regions. For example, biomes are not homogeneous throughout their extent, with variations in topography and microclimate creating environments with different conditions and resources, which in turn can affect the structuring of communities at the regional scale. The partitioning of total beta diversity into the nestedness and turnover components allows a more refined understanding of how these factors affect biological communities (Rosauer et al., 2014; Legendre, 2014; Soininen et al., 2018) and enables the testing of potential mechanisms. If species are responding to environmental dissimilarities, then a greater turnover of species will be expected for regions that have greater environmental dissimilarity. It is well-established that climate patterns are associated with latitude; they can be used as a proxy for environmental heterogeneity, and are associated with species richness gradients (Willig, Kaufman, & Stevens, 2003; Soininen et al., 2018). Consequently, a greater turnover of species is expected for regions located at lower latitudes, whereas nestedness should be greater for regions located at higher latitudes.

Several studies have found that spatial distance and environmental differences between sites are the main factors explaining beta diversity dissimilarity along a geographical gradient (Melo, Rangel, & Diniz-Filho, 2009; Rodriguez-Artigas, Ballester, & Corronca, 2016; Hu et al., 2018; Coccia & Fariña, 2019). Species' life history traits are important predictors in explaining beta diversity patterns. For example, communities comprised of species with limited dispersal capabilities are more likely to be influenced by spatial distances (Dobrovolski et al., 2012; Varzinczak, Moura, Lima, & Passos, 2019). Conversely, highly vagile species should be able to follow their environmental niche, being more affected by climatic and environmental factors and less so by spatial dynamics (Dobrovolski et al., 2012; Varzinczak, Lima, Moura, & Passos, 2018). However, recent studies on bat communities (i.e., species with high dispersal capability) along a geographical gradient have yielded contradictory results. While some studies have shown that differences in communities are mainly due to different environmental preferences (Stevens, López-González, & Presley, 2007; Stevens, 2013; López-González, Presley, Lozano, Stevens, & Higgins, 2015), others have shown that the spatial pattern was more effective in explaining bat diversity (Varzinczak et al., 2018) or both factors (environmental and geographical) influenced similarity in community composition (Varzinczak et al., 2019). A potential explanation for this controversy could be the scale of analysis. For instance, studies that evaluated bat diversity considering a larger scale, such as the neotropical region, showed that the spatial patterns was the most influential factor explaining differences in the diversity of bats (Varzinczak et al., 2018; López-Aguirre, Suzanne, Laffan, & Archer, 2019), whereas studies on a smaller scale, covering a single biome, demonstrated that climate was the most influential factor explaining bat species diversity (Stevens, 2013; Stevens et al., 2007; López-González et al., 2015). It is possible that spatial patterns will be more important at a larger scale because this increases the chances of including geographical barriers (Varzinczak et al., 2018) that are capable of imposing stronger physiological and metabolic constraints (Zuloaga & Kerr, 2017).

Contradictory results, such as the ones presented above for bat species, lead to questions such as “how do species distribution patterns change when the analyses are conducted at different spatial scales?” One should expect spatial factors to have a higher influence in explaining species diversity as one increases the scale of analysis, but should we also expect to find changes in the processes (nestedness or turnover) explaining beta diversity differences? Because of the growing availability of data papers in ecology, particularly those regarding species distribution data, it is now possible to test the above hypotheses. Recently, a collection of species occurrence data from the Atlantic Forest has been made available. Known as “Atlantic: Data Papers from a biodiversity hotspot,” these datasets are organized by researchers Mauro Galetti and Milton Ribeiro, and all papers have been reviewed by specialists, one of which consists of a dataset for bat species (Muylaert et al., 2017).

In addition to the availability of these data, other factors make the bats of the Atlantic Forest biome an important topic for study. First, bats are distributed almost everywhere in the world (except at the poles) and have diverse life-histories and great dispersion capacity (Kalka, Smith, & Kalko, 2008). Secondly, the Atlantic Forest has a highly endemic biodiversity and is one of the most threatened ecosystems in the world (Scarano & Ceotto, 2015). This biodiversity hotspot suffers from strong landscape conversion, with remaining forest fragments often being too small for species persistence (Scarano & Ceotto, 2015). The biome covers the north of the Brazilian coast to west of Paraguay and Argentina (Ribeiro, Metzger, Martensen, Ponzoni, & Hirota, 2009). Because of its large latitudinal range (> 30 degrees), the Atlantic Forest includes a diverse mosaic of habitats with a rich biodiversity. It is currently classified into ten distinct ecoregions (biogeographic zones) (Olson et al., 2001), which were delimited on the basis information concerning both resident taxa and geo-climatic data. Because species respond to environmental and spatial gradients, the ecoregions should present a correlation between beta diversity components and geographic and environmental factors (Stevens, 2013; Anjos et al., 2018; López-Aguirre et al., 2019).

Considering the different interpretations of distribution patterns of bat species (Stevens et al, 2007; Stevens, 2013; López-Goznzalez, 2015; Varzinczak et al., 2018; Varzinczak et al., 2019) and the availability of a data set on the occurrence of bat species within the Atlantic Forest (Muylaert et al., 2017), we evaluated the association between bat community (beta diversity) composition and environmental and geographical variables. We did this hierarchically, first for the entire extent of the biome, and then by dividing it into three regions: north, centre and south. In table 1 we provide a summary of our hypotheses and their main predictions.

4.2. MATERIALS AND METHODS

4.2.1. The Atlantic Forest biome

Our study covers the Atlantic Forest, the second largest South American rainforest and one of the world’s biodiversity hotspots. The biome covers the north of the Brazilian coast to the east of Paraguay and Argentina (Ribeiro et al., 2009). It embraces a diverse mosaic of habitats with a rich biodiversity and was classified by Olson et al. (2001) into ten distinct ecoregions (Fig. 1a.). In the southern region: (1) Alto Paraná Atlantic forests (Alto Paraná), composed by deciduous and semi-deciduous forests; (2) Moist *Araucaria* pine forests (Araucaria); (3) Serra do Mar coastal forests (Serra do Mar), which consists of ombrophilous dense forest and (4) Campos Rupestres montane savanna (Campos Rupestres), which are high-elevation grasslands. In the central region: (5) Bahia coastal forests (Bahia Coastal) and (6) Bahia interior forests (Bahia Interior), both of which are semi-deciduous forests; and (7) Atlantic dry forests (Dry Forests), which are deciduous forests with enclaves of Cerrado savanna. In the northern region: (8) Pernambuco coastal forests (Pernambuco Coastal) and (9) Pernambuco interior forests (Pernambuco Interior), both of which are a mix of ombrophilous dense forest and ombrophilous open forest. Lastly, (10) Atlantic Coast restinga (Coast Restinga), which are *restingas* and mangroves that extend throughout the coast of the biome. The Dry Forests ecoregion was excluded from this study due to a lack of data for bat occurrences there.

4.2.2. Occurrence and geo-climatic data

Our study was based on 2,634 bat occurrence data points for 526 sites (coordinates) within the Atlantic Forest. Our data came from two sources. We extracted 1,795 occurrence data points for 160 sites from Muylaert et al. (2017). This dataset was compiled by bat specialists who also reviewed the taxonomy of the species and the coordinates of sampling sites. We then used the species list provided in Muylaert et al. (2017) to search for other occurrence records in speciesLink (data downloaded from http://splink.cria.org.br/). We obtained 838 occurrence records of bat species for 365 sites. We reviewed the dataset obtained from speciesLink according to how reliable the information was regarding: i) coordinates and site correspondence (we used google maps to check if the coordinates were referring to the places indicated), ii) correct taxonomy (we excluded species with “sp”, “ssp”, “cf” and “aff”), and iii) voucher specimens (we only considered records with specimens that were deposited in a museum). We also included a single occurrence record of *Natalus macrourus* (Trajano, 1984) from Parque Estadual Turístico do Alto Ribeira (PETAR), which was not considered by Muylaert et al. (2017) or SpeciesLink. Occurrence records belonging to the bat families Molossidae, Vespertilionidae and Embalonuridae were not included in our study because they are seldom captured in mist-nets (Nogueira, Pol &, Peracchi, 1999; Nogueira, Pol, Monteiro &, Peracchi, 2008), which was the predominant method used for sampling bat species represented in our data sources.

We obtained geo-climatic data from AMBDATA (available at http://www.dpi.inpe.br/Ambdata/index.php). The AMBDATA is an environmental dataset systematized from different data sources and commonly used in species distribution modelling. It consists of 19 bioclimatic variables at 30 arc-sec resolution (approx. 1 km). These are: 1) annual mean temperature (ºC); 2) mean diurnal range (ºC); 3) isothermality (mean diurnal range divided by annual temperature range, and multiplied by 100); 4) temperature seasonality (standard deviation *100); 5) maximum temperature of warmest month (ºC); 6) minimum temperature of coldest month (ºC); 7) temperature annual range (ºC); 8) mean temperature of wettest quarter (ºC); 9) mean temperature of driest quarter (ºC); 10) mean temperature of warmest quarter (ºC); 11) mean temperature of coldest quarter (ºC); 12) annual precipitation (mm); 13) precipitation of wettest month (mm); 14) precipitation of driest month (mm); 15) precipitation seasonality (coefficient of variation); 16) precipitation of wettest quarter (mm); 17) precipitation of driest quarter (mm); 18) precipitation of warmest quarter (mm); and 19) precipitation of coldest quarter (mm). We also included three non-climatic environmental variables from AMBDATA: 1) tree cover at a 500 m resolution (percentage); 2) elevation (m) at 3 arc-sec horizontal resolution (about 90 m) and a vertical resolution of 1 m and lastly, 3) declivity (degrees) generated from the elevation grid.

4.2.3. Beta diversity and the Generalized Dissimilarity Model (GDM)

There are various dissimilarity indices to measure changes in species composition between assemblages. We used the Sorensen index (βsØr) as implemented in Betapart package – R-project (Baselga & Orme, 2012). The input data table consists of the presence and absence of bat species for each study site (latitude and longitude). The package computes the total dissimilarity across all sites, and calculates turnover (Simpson's index, βsim) and nestedness (the difference between the Sorensen and Simpson index, βsne) components. Betapart returns cluster and dissimilarity matrices (between pairwise sites, and pairwise matrices of shared and non-shared species between sites) of turnover and nestedness.

First, we computed total beta diversity and its two components, nestedness and turnover, among the ten Atlantic Forest ecoregions proposed by Olson et al. (2001). Then we used the cluster and GDM results (Fig. 1a and 1b) to split the Atlantic Forest into three larger regions (southern, central and northern). Lastly, nestedness and turnover were calculated among the ecoregions making up each of the three regions. Each region was treated separately.

We used a species presence data frame with the coordinates of the occurrence sites to perform Generalized Dissimilarity Modeling (GDM), which analyses spatial patterns of dissimilarity in species composition pairwise between sites, using a nonlinear regression matrix. GDM quantifies dissimilarity using the Soresen Index (total beta diversity), then associates the turnover component (βsim) with biological distance (predictor variables) between sites (Fitzpatrick et al., 2013). The GDM procedure was used to predict bat species turnover across the Atlantic Forest based on environmental data. We used the R package "GDM" (Fitzpatrick & Lisk, 2016) to fit a GDM with the 22 environmental variables and the geographical distance (decimal degrees) between occurrence sites. The latter was calculated using the option "geo=T" in the function "gdm" of the GDM package. We used the parameter "weightType= richness" to weight sites relative to the number of species to minimize sampling bias. We chose not to exclude sites with few species (i.e. less than five) because in our database over 360 occurrence sites had five or fewer species, 90 sites had 10 species or fewer. Only 11 sites recorded 50% or more of the total number of species, so that excluding sites with few species would lead to a significant loss of data. Patterns of species turnover can be visualized on a raster with RGB colour standards; areas with similar colours contain similar assemblages. The GDM matrix regression used was I-spline with three basic functions, meaning that we used three points (the minimum) to form the I-spline curve (Fitzpatrick & Lisk, 2016). I-Splines can be visualized in a graph showing the relationship of predicted biological distance versus observed biological distance, providing an indication of how species composition changes along each environmental gradient (Fitzpatrick & Lisk, 2016). The selection of the best subset of predictors for our model followed Williams, Belbin, Austin, Stein, & Ferrier (2012): the initial model included all predictors; variables that contributed less than 2% to model explanation were iteratively removed. Variable removal was done on a stepwise basis beginning with the elimination of the variable that contributed the least to model explanation. Variables were reassessed regarding their importance and significance during each step of model reduction (i.e., backward elimination). Our model started with 23 predictor variables and ended with 11.

4.3. RESULTS

We included 59 bat species belonging to five families (Phyllostomidae, Noctilionidae, Natalidae, Thyropteridae and Furipteridae), 10 subfamilies and 35 genera. The Bahia Coastal ecoregion had the highest number of species (53 species, 89.83%), followed by Serra do Mar (45 species, 76.27%), Bahia Interior (38 species, 64.40%), Alto Paraná (37 species, 62.71%), Pernambuco Coastal (32 species, 54.23%), Coast Restinga (19 species, 32.20%), Pernambuco Interior (18 species, 30,50%), Araucaria moist forests (17 species, 28.81%) and Campos Rupestres (15 species, 25.42%) (See table S1.1 in pag. 106).

Our results indicate that geographic distance between sites as well as the spatial variation in climate and elevation are correlated with bat species turnover in the Atlantic Forest (Fig. 1 and 2; and figures in appendix S2 in pag. 111). The turnover component increases with the latitudinal distance between ecoregions (see pairwise indexes matrix between ecoregions in Table 2 and Fig. 1b). The mean dissimilarity (βsØr) between ecoregions was 0.65, with a mean turnover (βsim) of 0.36 and nestedness (βsne) of 0.29. The cluster and GDM analysis indicate three large groups of higher similarity in species composition for the Atlantic Forest: southern, central and northern regions (Fig. 1a, b). Dissimilarity in species composition among these regions presented similar values for the nestedness and turnover components (βsØr = 0.28; βsim = 0.13 and βsne = 0.15). The turnover component was larger and more important in separating the southern region from the central and northern regions (Table 3).

When beta diversity between ecoregions was analysed separately for each region (southern, central and northern), they presented higher values of nestedness, with the central and southern region having the lowest values of turnover (the turnover represented 13% of total beta diversity in the center region and 15% in the southern region) (see Table S2.3 in pag. 121, table S3.3 in pag. 123 and table S4.3 in pag. 125). The nestedness component was highest for ecoregions Araucaria and Campos Rupestres, which nested with Alto Paraná, Serra do Mar and Bahia Coastal (Table 2; and Table S2.3 in in pag. 121. For cluster see Fig S11.3 in pag. 123). Species dissimilarity between ecoregions that are located on the coast with ecoregions located in the interior by region (longitudinal gradient in the southern, central and northern regions of the Atlantic Forest), also presented higher nestedness. However, neighbouring ecoregions in the north, Pernambuco Coastal Forest and Pernambuco Interior forests, presented the highest turnover in species composition (42.5% of total beta diversity), similar to the values found among the northern, central and southern regions (Fig. 1a; Table 2; Table 3; Fig. S8.3 in pag. 120; and Table S4.3 in pag. 125).

The GDM explained 40% of the observed species turnover for the Atlantic Forest. The variables with greatest predictive power were: geographic distance, elevation, precipitation of warmest quarter, precipitation of coldest quarter, mean temperature of wettest quarter and minimum temperature of coldest month (Fig. 1b, Fig. 2 and see Appendix S2 in pag. 114). The non-explained variation in GDM could be the result of biotic interactions and other factors (e.g., historical processes), which were not considered.

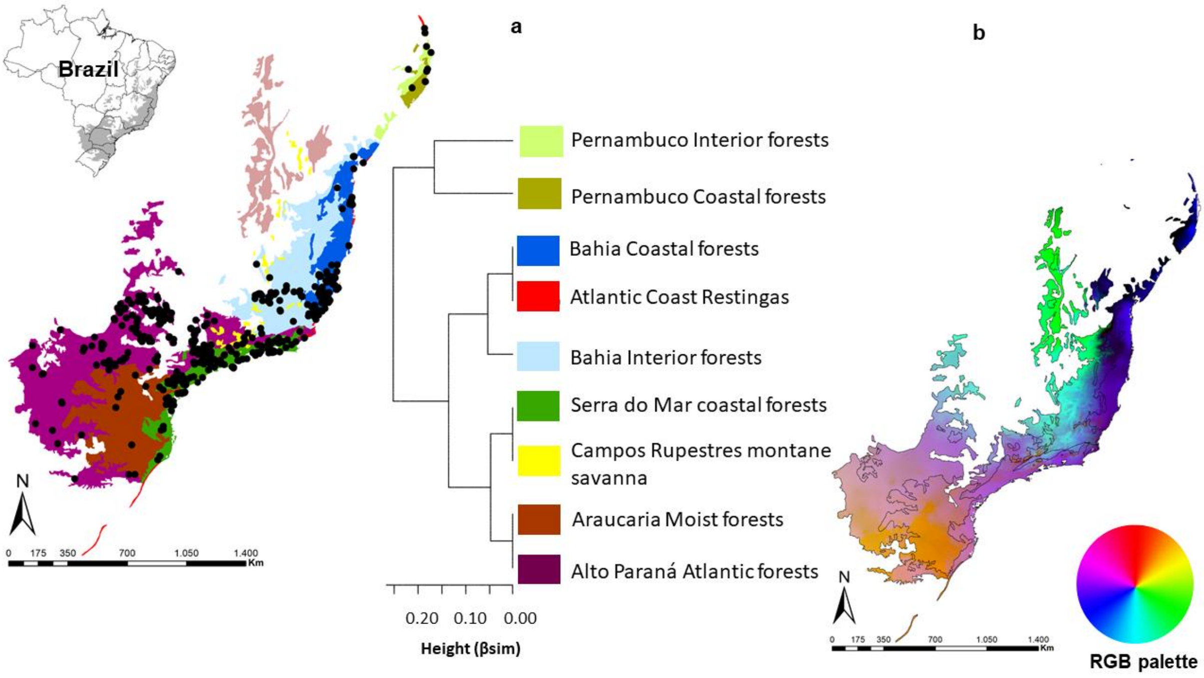


Figure 1. a) Atlantic Forest ecoregions with bat study sites (coordinates) (black dots). The cluster of the turnover component (βsim) provides values (height) from zero (same species found in both ecoregions) to one (no shared species between ecoregions). **b)** Map of bat species turnover based on geo-climatic predictors, the result of a Generalized Dissimilarity Model (GDM). The map is represented by RGB palette, colours represent the species composition gradient (βsim) based on environmental variables. Similar colors represent communities with similar species composition. GDM explained 40% of the model, so the color differences in the RGB map are a reflection of this explained part. There may be differences in the RGB map that the other 60% of the model did not explain.

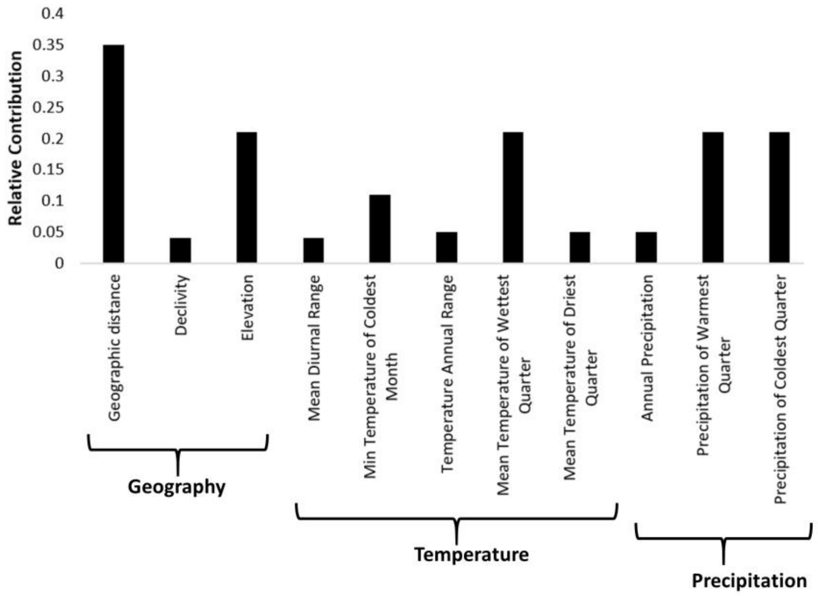


Figure 2. Eleven geo-climatic predictors that were significant predictors of bat species composition (βsim) in the Atlantic Forest according to a Generalized Dissimilarity Model (GDM): geographical distance (decimal degrees); declivity (degrees); elevation (m); mean diurnal range (ºC); minimun temperature of coldest month (ºC); annual temperature range (ºC); mean temperature of wettest quarter (ºC); mean temperature of driest quarter (ºC); annual precipitation (mm); precipitation of warmest quarter (mm) and precipitation of coldest quarter (mm). The relative contribution of each predictor indicates its relative importance in contributing to biological turnover while holding all other variables constant. Hence, the relative contributions will not sum to 100%.

4.4. DISCUSSION

Our results indicate that bat species turnover is the main component in the dissimilarity among bat communities in the Atlantic Forest, under the influence of geographical distance and latitude. The larger the difference in latitude between occurrence sites, the larger was the turnover of species. This biogeographical pattern is common for many regions of the globe and for several taxa (Soininen et al., 2018). What is unique about our study, however, is the importance of species loss (nestedness component) in determining beta diversity dissimilarity when communities are analysed at smaller scales – among regions (north, centre and south), and among ecoregions within each region. The southern region was the most dissimilar, being highly nested with the centre and north regions, which explained why occurrence sites located furthest from the south had the greatest turnover of species. This distinctive pattern is clearly observed in the orange patch of Figure 1b, which covers the ecoregions Araucaria forest and the southern part of the Alto Paraná ecoregion, separating the warmer (centre and north) from the coldest (south) regions of the Atlantic Forest biome. We also found that nestedness was the main pattern explaining dissimilarity longitudinally, independent of latitude. This gradient in species loss from the coastal ecoregions to the interior could be explained by differences in temperature, elevation and precipitation, which are known environmental filters for bat species (Stevens, 2013). The GDM analysis was able to explain 40% of the turnover based on environmental and geographic variables, but we emphasize that part of this 40% may be mere chance. The other 60% that is not explained by the model may be due to historical, evolutionary and ecological filters (eg. biotic interactions), which were not tested.

In the southern region of the Atlantic Forest, pronounced changes in species composition occurred above 1000 m a.s.l., showing a gradient of species richness loss in ecoregions at high elevation: Araucaria and Campos Rupestres. The low temperatures associated with higher elevations separate the Araucaria and Campos Rupestres ecoregion from Alto Paraná and Serra do Mar, and could be a limiting factor for the occurrence of several bat species. Flying is a costly activity, and because bats have a high ratio of body surface area to mass (because they are winged), they are more likely to lose heat to the environment and need a higher metabolic rate to maintain their body temperatures (Stones & Wiebers, 1965). There is also an indirect influence, since temperature and precipitation influence plant phenology, limiting the availability of food resources (Newton, 2003; Marques, Roper, & Savalaggio, 2004; Stevens, 2013). Thus, lower resource availability coupled with higher energetic demands for bats living in colder climates will be a strong limiting filter for several bat species, and only species adaptated to colder climates will occur in Araucaria forests. Our study did find that all of the bat species occurring in the Araucaria ecoregion (see table S1.1 in pag. 106) have a broad distribution and are commonly sampled in almost all of the Brazilian biomes (Reis, Peracchi, Batista, Lima, & Pereira, 2017). Species with large range sizes face greater heterogeneity in environmental conditions and are capable of maintaining viable populations under different climatic and environmental conditions (Brown, 1984; Devictor, Romain, & Frédéric, 2008; Estrada et al., 2015). Also, most of the bat species from the Araucaria ecoregions (e.g. species of the genera *Artibeus*, *Sturnira*, *Carollia*, *Anoura*, *Platyrrhinus*) are known to occur in primary and secondary forests, as well as anthropogenic habitats (Reis et al., 2017), suggesting that bat species occurring in the Araucaria forests have a more plastic response to climatic and environmental conditions. The fact that of the 48 bat species that occur in the southern Atlantic Forest, only two (*Macrophyllum macrophyllum* and *Noctilio albiventris*) were not found in the central and northern areas, supports this interpretation. Conversely, 11 bat species were exclusively associated with the two warmer (central and northern) regions (*Glyphonycteris daviesi*, *Dryadonycteris capixaba*, *Phyllostomus elongatus*, *Lichonycteris degener*, *Trinycteris nicefori*, *Rhinophylla pumilio*, *Dermanura gnoma*, *Platyrrhinus incarum*, *Uroderma bilobatum*, *Micronycteris schmidtorum* and *Lophostoma brasiliense*). These species are also present in other warmer regions of Brazil, such as the Amazon (including savannas), Cerrado and Caatinga, which suggests that temperature is an important limiting factor in their distribution (Reis et al., 2017).

The lowest hierarchical level – ecoregions within each region – indicated that nestedness was the main factor influencing differences in beta diversity. In this case, the interior ecoregions were nested within the coastal ecoregions. This longitudinal pattern seems to follow an elevational gradient, particularly in the south and north of the Atlantic Forest (see elevation spline curve in Figure S1.2 in pag. 114). In the south, there is a system of mountains and escarpments that runs for 1,500 km along the Atlantic coast. The ecoregion Serra do Mar occurs on the eastern side of the mountain range along a 100 km wide strip with lowland forests on the coastal plains and upper montane forests in mountainous areas (~ 1,500 m a.s.l.). This creates a strong vegetation gradient and this ecoregion is known for its remarkable richness and endemism in plants (Werneck, Sobral, Rocha, Landau, & Stehmann, 2011), amphibians (Campos & Lourenço-de-Moraes, 2017), birds (Silva, Souza, & Castelletti, 2004) and mammals (Costa, Leite, Fonseca, & Fonseca, 2000). The interior forests are located on the western side of this mountainous region, and all have lower bat species richness and comprised subsets (i.e., were highly nested) of the bat fauna from the Serra do Mar ecoregion. For example, of the 37 bat species that occurred in Alto Parana, 34 of them also occurred in Serra do Mar ecoregion.

The same longitudinal pattern was recovered between Coast Restinga (an ecoregion that extends from the far north to the southern end of the Atlantic Forest coast) and the interior ecoregions. This longitudinal pattern seems to follow the precipitation regime, which in the central and northern region of the biome decreases dramatically from the coast to the interior (see spline curves Fig S2.2 in pag. 115). Coastal regions hosted several bat species that did not occur in the interior (such as *Lampronycteris brachyotis*, *Lonchophylla mordax*, *Carollia brevicauda*, *Uroderma magnirostrum*, *Vampyrodes caracioli*, *P. incarum*, *D. gnoma*, *T. nicefori*, *G. daviesi*, *L. degener*, *P. elongatus* and *M. schimidtorum*), which resulted in greater dissimilarity between bat communities. Moreover, ecoregions in the interior presented a high number of shared bat species with coastal ecoregions and only a low number of species replacement (or turnover), which indicates that many species are lost along the longitudinal gradient of the Atlantic Forest. However, the Pernambuco ecoregions, which are located in the lower latitudes of the biome, have some climatic peculiarities that are not found in other regions of the Atlantic Forest: 1. there is no marked difference in elevation between the Pernambuco

Coastal and Pernambuco Interior; 2. despite there being a drop in temperature during the wettest season of the year in the Pernambuco Interior ecoregion, temperatures are not as low as in other regions of the Atlantic forest (Fig S3.2 in pag. 116); and 3. there is a pattern of higher precipitation during colder periods in the north that does not occur in other regions of the Atlantic forest . These environmental conditions may explain why Pernambuco Coastal and Pernambuco Interior had the highest turnover of bat species (40% dissimilarity), relative to neighbouring ecoregions of the Atlantic Forest.

Determining species distribution is a challenging task. We acknowledge that there are sampling gaps for the chiropteran from the Atlantic forest, as can be seen in Fig. 1a. However, sampling points are not concentrated in small patches for most of the ecoregions. In the centre of the biome, the southern portions of the Bahia Coastal and Bahia Interior ecoregions are better sampled, but, the central region is more similar in composition to the northern than the southern region. The two ecoregions that make up the north, Pernambuco Interior and Pernambuco Coastal, are small and have few study sites, but over 50% of the species included in our study were present in Pernambuco Coastal region, which suggests that sampling gaps are a minor issue. The GDM analysis explained less than 50% of the dissimilarity among communities, which indicates the importance of historical factors in determining species distributions. Despite our results uphold previous studies that indicated that the central and northern regions served as refugia during past climatic changes (i.e., they have higher species richness) in the Atlantic Forest (Carnaval & Moritz, 2008; Carnaval et al., 2014), this hypothesis has yet to be tested for bats. Our findings showed that the composition of bat communities varied tremendously throughout the Atlantic Forest. This corroborates the importance of partitioning beta diversity (turnover and nestedness) and of analysing it at different scales to understand how environmental variation in geographic space influences species distribution patterns. The patterns identified here have important implications for understanding how bats respond to changes in the environment, which in turn helps predict how environmental change can interfere with species distributions. For example, we found that climatic factors have a strong influence on the distribution pattern of bats, and changes in precipitation and temperature may drive the configuration of beta diversity components. Species present in the coastal ecoregions of the Atlantic Forest, which are warmer, wetter and where forest refugia have been predicted, may respond negatively to climate change if the climate of the coastal ecoregions were to become more similar to the more unstable climatic zones of the interior ecoregions of the Atlantic Forest. Although this potentially negative impact needs to be tested, with the use of species distribution models and different climate scenarios, our results indicate the importance of environmental factors as predictors of bat species composition, and that they should be taken into account in biogeographic, ecological and conservation studies.

TABLES

Table 1. Summary of our hypotheses and their main predictions. The table shows the predictions and respective key references supporting the hypothesis. The hypotheses 1 and 2 were accepted, and hypotheses 3 and 4 were partially accepted.

Hypothesis	Predictions	Key references
H_1. Species turnover will be associated with geographical distance and will be the main component of beta diversity in the latitudinal gradient; for example, the more distant the latitudinal sites, the greater the	Because of flight ability bats should manage to track their environmental preferences. Therefore, variation in bat species composition should be more influenced by geographical distance and less so by local factors. Composition will be affected by environmental	Soininen et al., 2018; Varzinczak et al., 2019 and López-Aguirre et al., 2019.

turnover.	changes at a large scale, for example, the latitudinal gradient. Thus, the greater the distance between ecoregions, the bigger the turnover will be.	
H_2. The main process determining compositional dissimilarity at a longitudinal gradient (from the coast to the interior) will be nestedness.		
H_3. The ecoregions located in the south of the Atlantic Forest, which are at higher latitudes and have colder climates, will have the lowest richness and turnover rate of the Atlantic Forest.	Climate patterns are associated with latitude, which is also a proxy for species richness and turnover gradients. Also, bats have high physiological demand (energy and metabolism) because of their flight capability. Together with their high ratio of body surface area to mass, several bat species will have difficulties coping with cold climates.	Stevens & Willig, 2002; Willig et al., 2003; Dobrovolski et al., 2012 and Soininen et al., 2018.
H_4. The ecoregions located at lower latitudes, in the centre and north, will present the highest richness and species turnover index.		

Table 2. Pairwise dissimilarity index matrix of the turnover (βsim) and nestedness (βsne) component of bats species between the Atlantic Forest ecoregions (according to Olson et al. 2001) of Brazil. This matrix shows the results of the Beta diversity analysis (Betapart/R-project) and the index was calculated using the presence and absence of bat species for each ecoregion. Total turnover and nestedness are also presented.

	Alto Paraná	**Araucaria**	**Coast Restinga**	**Bahia Coastal**	**Bahia Interior**	**Campos Rupestres**	**Pernambuco Coastal**	**Pernambuco Interior**
	Turnover (βsim) - 0.361194							
Araucaria	0.00000000							
Coast Restinga	0.10526316	0.35294118						
Bahia Coastal	0.11111111	0.00000000	0.00000000					
Bahia Interior	0.25000000	0.05882353	0.05263158	0.05263158				

Campos Rupestres	0.00000000	0.13333333	0.40000000	0.00000000	0.06666667			
Pernambuco Coastal	0.25000000	0.23529412	0.26315789	0.06250000	0.25000000	0.33333333		
Pernambuco Interior	0.16666667	0.52941176	0.33333333	0.00000000	0.16666667	0.66666667	0.16666667	
Serra do Mar	0.05555556	0.00000000	0.05263158	0.11111111	0.13157895	0.00000000	0.21875000	0.05555556
	Nestedness (βsne) - 0.2980416							
Araucaria	0.35849057							
Coast Restinga	0.27655502	0.03594771						
Bahia Coastal	0.16978777	0.51428571	0.47222222					
Bahia Interior	0.02027027	0.35935829	0.31578947	0.15615963				
Campos Rupestres	0.41176471	0.05416667	0.07058824	0.55882353	0.40503145			
Pernambuco Coastal	0.04411765	0.23409364	0.18782250	0.23161765	0.06428571	0.24113475		
Pernambuco Interior	0.27777778	0.01344538	0.01801802	0.49295775	0.29761905	0.03030303	0.23333333	
Serra do Mar	0.10493827	0.45161290	0.38486842	0.07256236	0.07324033	0.50000000	0.13189935	0.40476190

Table 3. Pairwise index matrix of the turnover (βsim) and nestedness (βsne) component of bat species among three regions (south, central and north) of the Atlantic Forest of Brazil. South region includes

the Serra do Mar, Alto Parana, Araucarias and Campos Rupestres ecoregions; Central region includes Bahia Coastal, Bahia Interior and Coast Restinga ecoregions; and the North region includes Pernambuco Coastal and Pernambuco Interior ecoregions. This matrix shows the result of the Beta diversity analysis (Betapart/R-project) and the index was calculated using the presence or absence of bat species for each of the three regions. Total turnover, nestedness and total beta diversity are also presented.

	South	**Central**
	Tunover (βsim) - 0.1318681	
Central	0.08333333	
North	0.17142857	0.05714286
	Nestedness (βsne) - 0.1564202	
Central	0.06229773	
North	0.12977625	0.20952381
	Beta diversity (βsØr) - 0.2882883	
Central	0.1456311	
North	0.3012048	0.2666667

DATA AVAILABILITY STATEMENT

The authors are willing to share the data, including distribution points and data analysis scripts, in a public repository (Dryad) if the article is accepted for publication. We choose not to share prior to acceptance for the sake of ensuring that our results are not reproduced by third parties. We are willing to supply any further information and we appreciate your understanding.

REFERENCES

Anjos, L., Volpato, G. H., Lopes, E. V., Willrich, G., Bochio, G. M., Arakaki Lindsey, B. R., … Lima, M. R. (2018). Distributions of birds and plants in ecoregions: Implications for the conservation of a neotropical biodiversity hotspot. *Austral Ecology*, 43(7), 839-849.

Baselga, A. & Orme, C. D. L. (2012). Betapart: an R package for the study of beta diversity. *Methods in Ecology and Evolution*, 3, 808-812.

Brown, J. H. (1984). On the relationship between abundance and distribution of species. *The American Naturalist*, 124, 255-279.

Campos, F.S. & Lourenço-de-Moraes, R. (2017). Anurans from the mountain chain Serra do Mar: a critical area for amphibian conservation in the Atlantic Forest, Brazil. *Herpetology Notes*, 10, 547-560.

Carnaval, A. C. & Moritz, C. (2008). Historical climate modelling predicts patterns of current biodiversity in the Brazilian Atlantic forest. *Journal of Biogeography*, 35, 1187–1201.

Carnaval, A. C., Waltari, E., Rodrigues, M. T., Rosauer, D., VanDerWal, J., Damasceno, R... Moritz, C. (2014). Prediction of phylogeographic endemism in an environmentally complex biome. *Proceedings Royal Society Biological Sciences*, 281, 14–61.

Chao, A. & Ricotta, C. (2019). Quantifying evenness and linking it to diversity, beta diversity, and similarity. *Ecology*, doi:10.1002/ecy.2852

Coccia, C., & Fariña, J. M. (2019). Partitioning the effects of regional, spatial, and local variables on beta diversity of salt marsh arthropods in Chile. *Ecology and Evolution*, 9(5), 2575–2587.

Coelho, M. S., Carneiro, M.A.A., Branco, C.A., Borges, R.A.X., & Fernandes, G.W. (2018). Species turnover drives β-diversity patterns across multiple spatial scales of plant-galling interactions in mountaintop grasslands. *PLoS One*, 13, e0195565.

Costa, L. P., Leite, Y. L. R., Fonseca, G. A. B., & Fonseca, M. T. (2000). Biogeography of South American Forest Mammals: Endemism and Diversity in the Atlantic Forest1. *Biotropica*, 32(4b), 872–881.

Devictor, V., Romain, J., & Frédéric, J. (2008). Distribution of specialist and generalist species along spatial gradients of habitat disturbance and fragmentation. *Oikos* 117, 507–514.

Dobrovolski, R., Melo, A. S., Cassemiro, F. A. S., & Diniz-Filho, J. A. F. (2012). Climatic history and dispersal ability explain the relative importance of turnover and nestedness components of beta diversity. *Global Ecology and Biogeography* 21(2):1-7.

Estrada, A., Meireles, C., Morales-Castilla, I., Poschlod, P., Vieites, D., Araújo, M. B., & Early, R. (2015). Species' intrinsic traits inform their range limitations and vulnerability under environmental change. *Global Ecology and Biogeography*, 24(7), 849–858.

Fitzpatrick, M. & Lisk, M. (2016). Using the R package gdm to analyze and map biodiversity patterns. R package version 1.3.11.

Fitzpatrick, M.C., Sanders, N.J., Normand, S., Svenning, J.C., Ferrier, S., Gove, A.D., & Dunn, R.R. (2013). Environmental and historical imprints on beta diversity: insights from variation in rates of species turnover along gradients. *Proceedings of the Royal Society*, 280, 20131201.

Gianuca, A.T., Declerck, S.A.J., Lemmens, P., & De Meester, L. (2017). Effects of dispersal and environmental heterogeneity on the replacement and nestedness components of β-diversity. *Ecology,* 98(2), 525-533.

Hu, Y., Ding, Z., Jiang, Z., Quan, Q., Guo, K., Tian, L., … Gibson, L. (2018). Birds in the Himalayas: What drives beta diversity patterns along an elevational gradient? *Ecology and Evolution*, 8(23), 11704–11716. doi:10.1002/ece3.4622.

Kalka, M.B., Smith, A.R., & Kalko, E.K. (2008). Bats limit arthropods and herbivory in a tropical forest. *Science*, 320(5872), 71.2008.

Legendre, P. (2014). Replacement and richness difference components. *Global Ecology and Biogeography*, 23, 1324–1334.

Leigh, E. G., O'Dea, A., & Vermeij, G. J. (2014). Historical biogeography of the Isthmus of Panama. *Biological Reviews of the Cambridge Philosophical Society*, 89, 148– 172.

López-Aguirre, C., Suzanne, J.H., Laffan, S.W., & Archer, M. (2019). Zoogeographical regions and geospatial patterns of phylogenetic diversity and endemism of New World bats. *Ecography*, 42, 1188–1199.

López-González, C., Presley, S. J., Lozano, A., Stevens, R. D., & Higgins, C. L. (2015). Ecological biogeography of Mexican bats: The relative contributions of habitat heterogeneity, beta diversity, and environmental gradients to species richness and composition patterns. *Ecography*, 38, 261–272.

Marques, M. C. M., Roper, J. J., & Savalaggio, A. P. B. (2004). Phenological patterns among plant life-forms in a subtropical Forest in southern Brazil. *Plant Ecology*, 173: 203–213.

McGill, B.J., Dornelas, M., Gotelli, N.J., & Magurran, A.E. (2015). Fifteen forms of biodiversity trend in the Anthropocene. *Trends Ecology Evolution*, 30, 104–113.

Melo, A. S., Rangel, T. F. L. V. B., & Diniz-Filho, J. A. F. (2009). Environmental drivers of beta-diversity patterns in New-World birds and mammals. *Ecography*, 32(2), 226–236.

Muylaert, R.D.L., Stevens, R.D., Esbérard, C.E.L., Mello, M.A.R., Garbino, G.S.T., Varzinczak, L.H. ... Galetti, M. (2017). ATLANTIC BATS: a data set of bat communities from the Atlantic Forests of South America. *Ecology*, 98(12), 3227.

Newton, I. (2003). *The speciation and biogeography of birds* (1st ed.). London, Academic Press.

Nogueira, M. R., Pol, A., Monteiro, L. R., & Peracchi, A.L. (2008). First record of Miller's mastiff bat, *Molossus pretiosus* (Mammalia: Chiroptera), from the Brazilian Caatinga. *Chiroptera Neotropical*, 14 (1), 346–353.

Nogueira, M. R., Pol, A., & Peracchi, A.L. (1999). New records of bats from Brazil with a list of additional species for the chiropteran fauna of the state of Acre, western Amazon basin. *Mammalia*, 63 (3), 363–368.

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N… Kenneth, R. K. (2001). Terrestrial Ecoregions of the World: A New Map of Life on Earth. *BioScience*, 51(11): 933-938.

Reis, N.R., Peracchi, A.L., Batista, C.B., Lima, I.P., & Pereira, A.D. (2017). *História natural dos morcegos brasileiros – chave de identificação de espécies* (1st ed.). Rio de Janeiro, Technical Books Editora Ltda.

Ribeiro, M.C., Metzger, J.P., Martensen, A.C., Ponzoni, F.J., & Hirota, M.M. (2009). The Brazilian Atlantic Forest: how much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation*, 142, 1141–1153.

Rodriguez-Artigas, S., Ballester, R., & Corronca, J. (2016). Factors that influence the beta-diversity of spider communities in northwestern Argentinean Grasslands. *PeerJ*, 4:e1946; DOI 10.7717/peerj.1946.

Rosauer, D. F., Ferrier, S., Williams, K. J., Manion, G., Keogh, J. S., & Laffan, S. W. (2014). Phylogenetic generalised dissimilarity modelling: A new approach to analysing and predicting spatial turnover in the phylogenetic composition of communities. *Ecography*, 37, 21–32.

Scarano, F.R. & Ceotto, P. (2015). Brazilian Atlantic forest: impact, vulnerability, and adaptation to climate change. *Biodiversity and Conservation*, 24, 2319-2331.

Silva, J.M.C., Souza, M.C., & Castelletti, C.H.M. (2004). Areas of endemism for passerine birds in the Atlantic forest, South America. *Global Ecology and Biogeography*, 13, 85–92

Socolar, J. B., Gilroy, J. J., Kunin, W. E., & Edwards, D. P. (2016). How should beta-diversity inform biodiversity conservation? *Trends in Ecology and Evolution*, 31, 67–80.

Soininen, J., Wang, J., & Heino, J. (2018). A meta-analysis of nestedness and turnover components of beta diversity across organisms and ecosystems. *Global Ecology and Biogeography*, 27(1), 1-14.

Stevens, R. D. (2013). Gradients of bat diversity in Atlantic Forest of South America: Environmental seasonality, sampling effort and spatial autocorrelation. *Biotropica*, 45, 764–770.

Stevens, R. D., López-González, C., & Presley, S. J. (2007). Geographical ecology of Paraguayan bats: Spatial integration and metacommunity structure of interacting assemblages. *Journal of Animal Ecology*, 76, 1086–1093.

Stevens, R.D. & Willig, M.R. (2002). Geographical ecology at the community level: perspectives on the diversity of New World bats. *Ecology*, 83(2), 543-560.

Stones, R. C. & Wiebers, J. E. (1965). A review of temperature regulation in bats (Chiroptera). *American Midland Naturalist*, 74, 155-167.

Trajano, E. (1984). Ecologia de populações de morcegos cavernícolas em uma região cárstica do sudeste do Brasil. *Revista Brasileira de Zoologia*, 2(5), 255-320.

Varzinczak, L.H., Lima, C.S., Moura, M.O., & Passos, F.C. (2018). Relative influence of spatial over environmental and historical processes on the taxonomic and phylogenetic beta diversity of Neotropical phyllostomid bat assemblages. *Journal of Biogeography*, 45, 617–627.

Varzinczak, L.H., Moura, M.O., Lima, C.S., & Passos, F.C. (2019). How do bat, rodent, and marsupial communities respond to spatial and environmental gradients? Insights from a deconstruction of mammal beta diversity from the Atlantic Forest of South America. *Oecologia*, 189(4), 851-861.

Werneck, M.D.S., Sobral, M.E.G., Rocha, C.T.V., Landau, E.C., & Stehmann, J.R. (2011). Distribution and Endemism of Angiosperms in the Atlantic Forest. *Natureza & Conservação*, 9, 188-193.

Whittaker, R.H. (1960). Vegetation of the Siskiyou Mountains, Oregon and California. *Ecological Monographs*, 22, 1-44.

Williams, K. J., Belbin, L., Austin, M. P., Stein, J. L., & Ferrier, S. (2012). Which environmental variables should I use in my biodiversity model? *International Journal of Geographical Information Science*, 26, 2009–2047.

Willig, M. R., Kaufman, D. M., & Stevens, R. D. (2003). Latitudinal gradients of biodiversity: Pattern, process, scale, and synthesis. *Annual Review of Ecology Evolution and Systematics*, 34, 273–309.

Zuloaga, J., & Kerr, J. T. (2017). Over the top: Do thermal barriers along elevation gradients limit biotic similarity? *Ecography*, 40, 478–486.

BIOSKETCH

Carolina Blefari Batista is broadly interested in the biogeography of bats. This work represents a component of her PhD work at Universidade Estadual de Londrina (UEL), Londrina/PR, Brazil, on the ecology, biogeography and conservation of bats in the Atlantic Forest.

Author contributions: CBB, IPL and MRL conceived the ideas; CBB conducted the data collection and analysed the data (Beta diversity and Generalized Dissimilarity Model); CBB led the writing with assistance from IPL and MRL.

5. CAPÍTULO 3

Downscaling the Atlantic Forest biodiversity hotspot: using the distribution of bats to find smaller hotspots of conservation priority

Carolina Blefari Batista[a]*; Isaac Passos de Lima[a]; Rafael Arruda[b]; Marcos Robalinho Lima[a]

[a] Programa de Pós-Graduação em Ciências Biológicas; Departamento de Biologia Animal e Vegetal; Centro de Ciências Biológicas; Universidade Estadual de Londrina; 86051-970, Londrina, Brazil; Phone: (+55) 43 3371-4911

[b] Instituto de Ciências Naturais, Humanas e Sociais; Universidade Federal de Mato Grosso; Câmpus Universitário de Sinop; 78550-728, Sinop, Brazil; Phone: (+55) (66)3533-3118

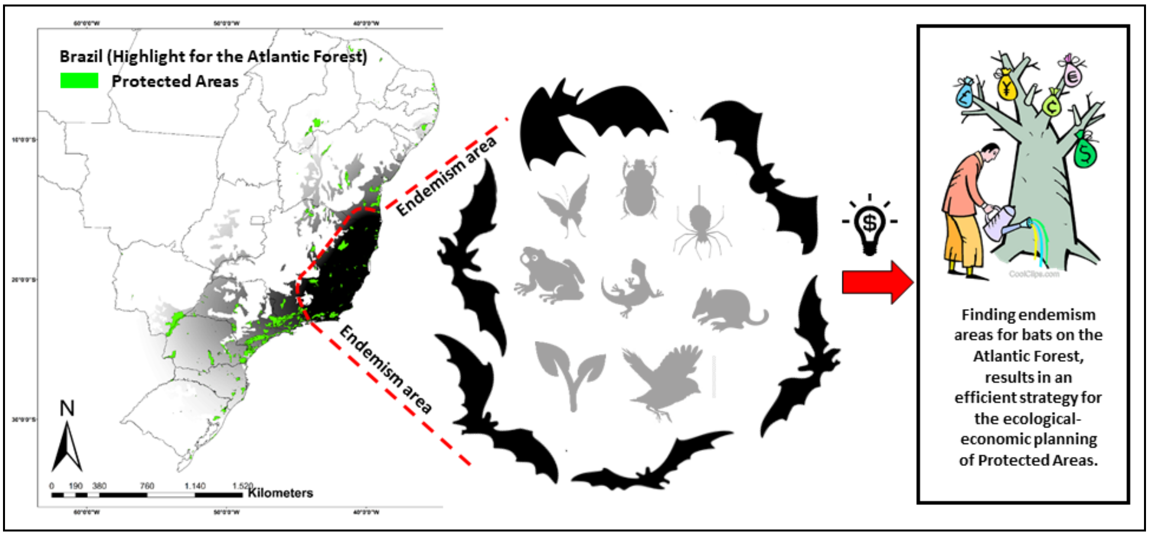
* Corresponding Author: blefaricarol@gmail.com

Abstract

The Atlantic Forest (AF) is one of most important and threatened biodiversity hotspots in the world and despite its wide geographical extension it has only 9.1% of its area under legal protection. This fact linked to the low investment of resources in conservation makes it necessary to find smaller hotspots of conservation priority in the biome. Finding an endemic area for bats can be an effective strategy in the indication of priority areas. Because bats have a high taxonomic and functional diversity, implying complex networks of interactions, this strategy can represent sites with high diversity of other taxa as well. We used a Geographic Interpolation of Endemism (GIE) analysis and indicated a congruence area for 58 of the 59 bat species included in this study, located in the center of the AF. Five species occur strictly in this area. We also superimposed the map of legally protected areas (PAs) with our map of endemism. We found that only 14 species had more than 50% of their records in PAs across the biome. Considering only PAs within the endemism area, five species have no occurrence in PAs, including a vulnerable species. Our area of endemism corroborates hotspots for other taxa. Therefore, we present an efficient strategy in the planning of PAs in the AF, implying that efforts for the conservation of biodiversity will be more efficient an increase in the cost-benefit relationship in the establishment of PAs.

Keywords: Endemism area, Chiroptera, GIE, protected areas, efficient strategy.

Graphical abstract



Finding endemism areas for bats on the Atlantic Forest, results in an efficient strategy for the ecological-economic planning of Protected Areas.

5.1. Introduction

Human activities have triggered biodiversity loss at higher rates than those seen for natural extinctions. In fact, mankind is facing very fast extinction rates, mainly caused by climate change and habitat loss (Dirzo et al., 2014; Vellend et al., 2017). Meanwhile, there are still several deficits in global strategy for biodiversity conservation, such as low budgets and incorrect appllication of scarce resources (Johnson et al., 2017). In the rise of a future economic crisis due to the COVID-19 pandemic, experts are concerned that investment on conservation will be reduced, drawing attention to the importance of conservation biologists communicating the benefits of biodiversity conservation to society (Corlett et al., 2020). Thus, one of the greatest challenges for conservationists is to pinpoint where limited resources should be concentrated and applied, prioritizing certain areas in detriment of others (Di Minin et al., 2017).

Several strategies have been employed to indicate priority conservation areas whose criteria vary according to the objective. Focus may be on conservation of rare species, endemic species, endangered species, general biodiversity maintenance or habitat conservation to keep ecosystem services and factors (Asaad et al., 2016). Since resources are scarce, the efficiency of priority areas regarding costs depends on a selection of strategies that comprises a multiple criteria dimension to properly conserve biodiversity (including endemic, rare and vulnerable species) and the ecosystem services for the longest period possible. Thirty-six critical areas of biodiversity concentration (hotspots) have been pinpointed (Myers et al., 2000; Williams et al., 2011; Noss et al., 2015; CEPF, 2016). However, these biodiversity hotspots were determined for a larger scale, despite conservation efforts and strategies occurring on a much smaller scale (Jenkins; Pimm, 2006). In order to facilitate the focus of conservation efforts, it is necessary to find and pinpoint high diversity sites at a smaller scale, or rather “hotspots within hotspots” (Cañadas et al., 2014).

Regardless of the strategy employed, pinpointing priority areas and conserving biological diversity requires knowing and understanding how species are distributed and which factors determine their spatial distribution (Sigrist; Carvalho, 2008; Cañadas et al., 2014; Batista et al., 2020). Despite recent progress in computer and analytic methods for a better understanding of the processes involved in the distribution of species, this is still a challenging issue in ecology and biogeography. First, species are not randomly distributed and there are specific areas with great biodiversity concentration (Sigrist; Carvalho, 2008). Second, most studies determine areas of greater biodiversity or endemism by employing online-published databases or distribution maps of species (IUCN, for instance) (Sigrist; Carvalho, 2008). This may add mistakes when delimiting priority areas. Species do not respond in the same way to the limiting factors within the different habitats. Actually, it is quite challening to find congruent areas of species distribution (Oliveira et al., 2015). Databases and maps on species distribution can have several gaps (e.g. low sampling effort and lack of georeferenced information of the occurrence site), which leads to false absences (Hortal, 2008; Stokland et al., 2011). Databases may also be biased, since they are constructed over an arbitrary design, making it difficult to be used for biogeographic conservation studies (Hortal et al., 2007). Further, these gaps may also prove to be the result of a greater concentration of sampling efforts closer to human population centers, as has been reported for Angiosperms (Nelson et al. 1990; Werneck et al. 2011), or by the uneven representativeness of *taxa* in scientific collections (Ponder et al. 2001).

The Geographical Interpolation of Endemism (GIE) is one of the ways to delimitate priority areas by determining sites with the greatest biodiversity and number of endemic species, minimizing effects of species distribution gaps. This analysis was proved and tested (Oliveira et al., 2015) and allows one to overlap areas in species distribution bands that are sustained by at least one endemic species. Since GIE does not use grid cells in a distribution map, it allows the use of occurrence data with spatial gaps (Oliveira et al., 2015). As important as choosing the analytical method is to choose a group of organisms that could represent diversity and distribution of other *taxa* (Oliveira et al., 2019). GIE analysis has been employed for several *taxa*, such as plants (Castueira-Oliveira et al. 2020), invertebrates and vertebrates (Oliveira et al., 2015; Oliveira et al., 2017), and for different biogeographic regions (Castueira-Oliveira et al., 2020).

Due to the characteristics of bats and the Atlantic Forest global hotspot, the investigation on sites of endemism may be important to help choose priority areas for conservation. Areas of endemism comprise sites with high species distribution congruence and the presence of restrict species (Harold; Mooi, 1994). Bats are the second most diverse group in mammals, after rodents (Simmons, 2005). Such diversity is not just taxonomic, since the group includes different feeding habits, including items such as fruits, nectar, insects and other invertebrates, small vertebrates and even fish and blood (Kalka et al., 2008). They also use several types of shelters such as leaves, trunks, trunk hollows, rocks, karstic environments and even houses (Kalka et al., 2008). The above adaptations and the ability to fly makes bats a good model for biogeographic studies focused on conservation (Aguiar et al., 2016; Herkt et al., 2016), since its distribution may reflect other taxa distributions. The Atlantic Forest is one of most important biodiversity hotspots in the world (Myers et al., 2000), with areas considered to be biodiversity refuges due to its greater climatic stability, allowing a wider diversification of species (Carnaval et al., 2009). On the other hand, 72% of Brazilians live within the Atlantic Forest area (Ministério do Meio Ambiente, 2017) and only 9.1% of the area is under legal protection (Sobral-Souza et al., 2018), making the biome vulnerable to anthropogenic activities. Further, a comprehensive database on bat distribution in the Atlantic Forest (Atlantic Bats – Muylaert et al., 2017) was built and extensively reviewed by experts. This database is available and allows the development of more complex research with bats in this biome.

Since bats may be useful to identify smaller priority areas for conservation within a wider hotspot and that they could represent other taxa, increasing the cost-benefit ratio, this study looked at two main issues. First, where are the centers of greatest concentration and restriction of diversity of bats located within the limits of the global Atlantic Forest hostspot? and second, how much of these areas are already protected by current legislation? To answer those questions, we used the Bat distribution data for the Atlantic Forest and GIE analytic tools to determine the main congruence areas for the occurrence of bat species. Congruence regions were compared with legally protected areas at federal and state levels. This allowed us to quantify the extent of these areas of congruence that are under legal protection. The two strategies enabled the identication of conservation priority areas that are not yet protected by current legislation.

5.2. Methods

5.2.1. Database

Two databases were constructed: a database for bat richness and another for abundance indexes controlled by sampling effort. Both were required, since not all georeferenced sites used for richness data provide data on species abundance and sampling effort.

5.2.1.1. Bat richness in the Atlantic Forest

The *Atlantic Bats* database (Muylaert et al., 2017) was consulted. This database was prepared by experts who also reviewed species taxonomy and sampling sites coordinates of bat species occurrence records for the entire Atlantic Forest. From Muylaert et al. (2017) database, we retrieved a species list that allowed searching another repository (speciesLink - http://splink.cria.org.br/), because the database “Atlantic Bats” only takes into account records that include abundance data. The dataset retrieved from speciesLink was analyzed according to data reliability: i) correspondence of coordinates and sites (Google Earth maps were used to verify whether coordinates referred to the indicated sites); ii) correct taxonomy (species with “sp”,“ssp”, “cf” and “aff” were excluded); and iii) only records with specimens deposited in a museum as vouchers were taken into account. Furthermore, we identified the absence of an important record of *Natalus macrourus*, which was missing in Muylaert et al. (2017) and in speciesLink. Thus, our database also includes the single record of *N. macrourus* (by Trajano, 1984) at the Parque Estadual Turístico do Alto Ribeira (PETAR). We noticied that our database had few occurrence points for the northern region of the Atlantic Forest, so we also included bat occurrence records from the Atlantic Forest of northeastern Brazil (Souza et al., 2004; Campos et al., 2018; Nunes et al., 2018; Vargas-Mena et al., 2018). Records of bats species occurrence from families Molossidae, Vespertilionidae and Embalonuridae were not included in this database due to the difficulty in capturing them with the use of mist nets (Nogueira et al., 1999; Nogueira et al., 2008). Mist nets are the predominant method used to sample bat species in researched databases. To remove duplicates or very close coordinates of occurrence records, we applied a latitude and longitude filter with three and two decimal places, respectively. Then, we joined the columns of latitude and longitude plus species. Both the filter with two and three decimal places resulted in the exclusion of 470 duplicate occurrence records. Consequently, 2,829 bat occurrence data were retrieved, distributed in 535 sites (coordinates) for 60 species in the Atlantic Forest.

5.2.1.2. Abundance controlled by sampling effort (A/SE)

The *Atlantic Bats* (Muylaert et al., 2017) provides species´ abundance data. However, since sampling effort varied for each sampling site (coordinate), we filtered the database to select only the occurrence records provided with species abundance and sampling effort. We used this data to calculate the abundance index controlled by sampling effort (Abundance/Sampling effort or “A/SE”). Occurrence sites (coordinates) with no sampling effort data were recorded as 0 for this index. We elaborated “A/SE” indexes for 58 species (see distribution map for each species in pag. 127), distributed in 1,397 records for 133 occurrence sites, and retrieved from the *Atlantic Bats* database only.

5.2.2. Congruence area of bat distribution in the Atlantic Forest

We used GIE method as suggested by Oliveira et al. (2015). This method consists in five steps; (1) Determination of species distribution centroid, based on occurrence sites, using the bat richness database for the Atlantic Forest, compiled from published databases (see “Bat richness for the Atlantic Forest”, section 5.2.1.1). Centroid is determined by mean latitude and longitude values of the species´ occurrence sites. (2) Determination of species´ distribution range, or rather, the distance between the centroid and the most distant occurrence site. Distance is determined by Pythagoras theorem where the hypotenuse is the distance between the centroid and the most distant site. (3) Species are categorized into different groups by distance, with six distance classes of centroid influence: Class 1, species range of 0 to 300 km; Class 2, from 301 to 600 km; Class 3, from 601 to 900 km; Class 4, from 901 to 1,200 km; Class 5, from 1,201 to 1,500 km; Class 6, from 1,501 to 1,800 km; Class 7, from 1,801 to 2,171 km (Fig. 1; Table 1A in pag. 148). The above classification is important since several species may have the same or very close centroids, albeit with very distinct distributions. Categorization within different distance radii favors the comparison of congruence areas for species with similar distribution ranges. (4) Determination of the area of endemism for each class of distribution range using kernel algorithm. (5) Preparation of a consensus map involving the maps of the six distance classes. Microsoft Excel (version 2016) and GIE package inserted in ArcGIS 10.5 of ESRI (ArcGIS trial) were employed for this analysis.

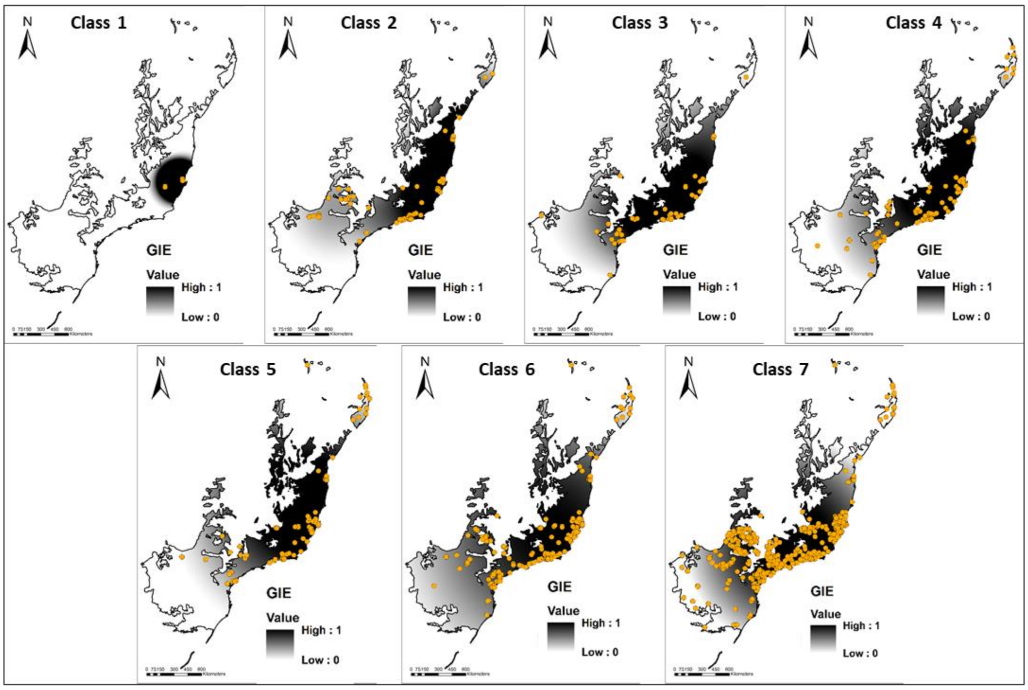


Fig. 1. Classification of 60 Atlantic Forest bat species from the distribution radius of the Geographic Interpolation of Endemism (GIE). The endemism area index varies from a scale of 0 to 1 (endemic area). Class 1, species range of 0 to 300 km; Class 2, from 301 to 600 km; Class 3, from 601 to 900 km; Class 4, from 901 to 1,200 km; Class 5, from 1,201 to 1,500 km; Class 6, from 1,501 to 1,800 km; Class 7, from 1,801 to 2,171 km. Orange dots represent georeferenced occurrence sites of each species' class.

5.2.3. Analysis of sampling effort

Database for bat richness and the shape file of the Atlantic Forest limits were employed to prepare hotspot maps indicating the greatest sampling efforts for bat capture. Analysis was undertaken using BioDinamica package (Oliveira, 2018) in Dinamica Ego software. The function employs kernel algorithm to interpolate georeferenced occurrence sites and generate a sampling effort map. Adjustments in the analysis includes Search radius, or rather, the sampling influence area. In other words, what is the influence area of the mist nets sampling for the capture of bats? As number, size and distribution of mist nets may vary according to sampled sites, three analyses were undertaken with different sampling influences: 10 km², 50 km² and 100 km².

5.2.4. Relationship between the distribution latitude band of Atlantic Forest species, richness and abundance.

We prepared rarefaction curves by extrapolation of species based on *Hill* series using `iNEXT` package (Hsieh, 2019) on an `R` environment (R Core Team, 2020). Rarefaction indicates observed bat richness as a function of sampling effort employed (occurrences sites – coordinates were used) and the *Hill* series-based extrapolation shows the number of species that may be introduced into the sample when the sampling effort is doubled. It is a modern technique which replaces previous ones that made inferences based on non-parametric metrics as jackknife, chao and bootstrap. Further, richness was calculated with the function "`diversityresult`" from `BiodiversityR` package (Kindt; Coe 2005). Richness calculated values were distributed on a scatterplot with latitudes on the X axis, with "`ggplot`" function from "`ggplot2`" package (Wickham 2009) within an `R` environment (R Core Team, 2020). The "A/SE" indexes were summed for each georeferenced site and plotted on a scatterplot in the same way as for richness.

5.2.5. Representativeness of state and federal Protected Areas for bat species in the Atlantic Forest

State and federal Protected Areas (PAs) were plotted (shape file available at https://www.mma.gov.br/areas-protegidas/cadastro-nacional-de-ucs/mapas.html) over the Atlantic Forest (shape file available at https://www.mma.gov.br/biomas/mata-atl%C3%A2ntica_emdesenvolvimento/mapas-da-mata-atl%C3%A2ntica) and the percentage of PAs was calculated within the congruence area indicated by GIE, using "calculate geometry" tool of the table attribute in ArcGis 10.5. We transformed Bat Richness sheet (occurrence by coordinates) into layers and selected only the occurrence sites within PAs. We then determined the number of species within PAs in the Atlantic forest and within the congruence area. Analysis were also performed in ArcGis 10.5 of ESRI (ArcGIS trial license).

5.3. Results

The GIE analysis detected a single congruence area (Fig. 2) for the distribution of 58 out of 59 bat species in the Atlantic Forest, based on the presence of five restricted species (*Micronycteris hirsuta*, *Micronycteris schmidtorum*, *Dryadonycteris capixaba*, *Glyphonycteris daviesi* and *Dermanura gnoma*) (Table 1A in pag. 148). Only *Noctilio albiventris* did not occur within the congruence area. Rarefaction curve and extrapolation showed that, if sampling effort were doubled (1070 sites), the final list would contain a total of 59 species (not different from the observed richeness), showing that our database for the

Atlantic Forest represents a reliable sample of bat species from Phyllostomidae, Noctilionidae, Furipteridae, Thyropteridae and Natalidae families, frequently captured by mist nets (Fig. 3). Analysis on sampling efforts revealed that the Serra do Mar region on the south coast of the Atlantic Forest, the northwest of the São Paulo state and the Biome´s central region are sampling hotspots, or rather, that current results are not merely a product of the sampling effort (Fig. 4).

Highest species richness lies within latitudes -25 and -19, whilst the greatest “A/SE” indexes are between latitudes -22 and -19. Richness and abundance peaks corroborate with the congruence area detected by GIE (Fig. 5). Although 58 out of 59 bat species have occurrence records within PAs throughout the Atlantic Forest, only 14 species had more than 50% of their records within these areas. If the congruence area alone is considered, five of the 58 species fails to occur in PAs (*Macrophyllum macrophyllum*, *Phylloderma stenops*, *Vampyrodes carccioli*, *Thyroptera tricolor*, and *Lonchorhina aurita* which is categorized as "Vulnerable" by “*Lista Vermelha da Fauna Ameaçada*”, ICMBio/MMA, 2018) and 34 species shows less than 50% of occurrence records in PAs (Table 1A in pag. 148). The map overlapping PAs and Atlantic Forest (Fig. 2) indicates that about 6.33% of the forest cover of the Atlantic Forest is legally protected, and of the total congruence area, 3.9% is legally protected.

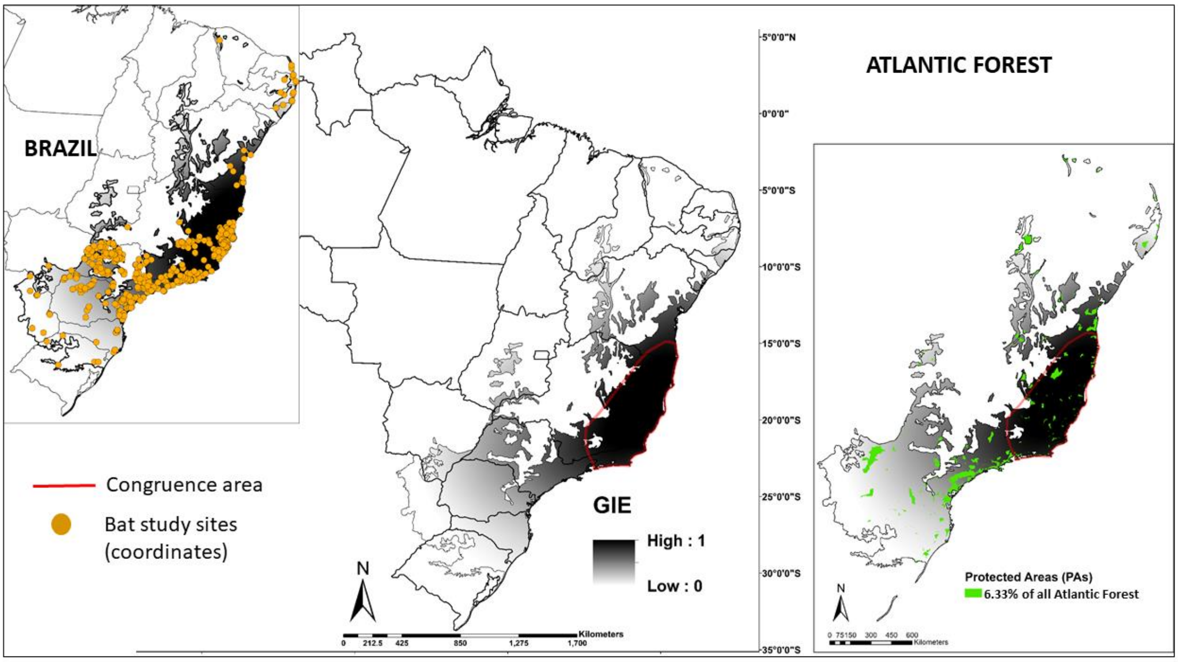


Fig. 2. Consensus map of the endemism area resulting from the Geographic Interpolation of Endemism (GIE) for 59 bat species of the Atlantic Forest, of which 58 are present in the congruence

area .The GIE index ranges from 0 (area with low or no congruence of species distribution and without restricted species) to 1 (area with high congruence of species distribution and with restricted species); and overlapping map of Protected Areas (PAs). About 6.33% of the forest cover of the Atlantic Forest is legally protected, and the congruence area features 3.9% of the legally protected area.

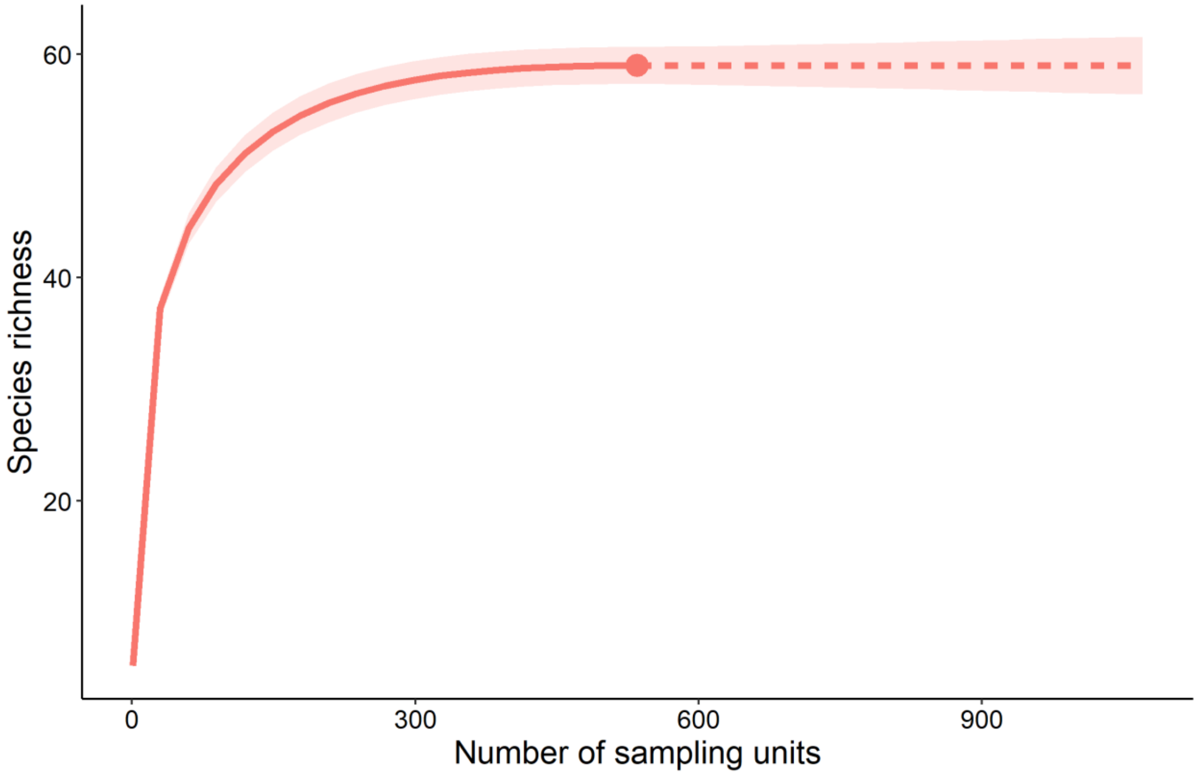


Fig. 3. Observed richness of 59 bat species (continuous line) as a function of the total number of sampling units (georeferenced locations) in the Atlantic Forest, with a 95% confidence interval for the Hill series. The dotted line represents the extrapolation of species richness in the study area if the sampling effort was doubled (the estimated final list would contain a total of 59 species - not different from the observed richness), showing that our database for the Atlantic Forest represents a reliable sample of bat species from Phyllostomidae, Noctilionidae, Furipteridae, Thyropteridae and Natalidae families, frequently captured by mist nets

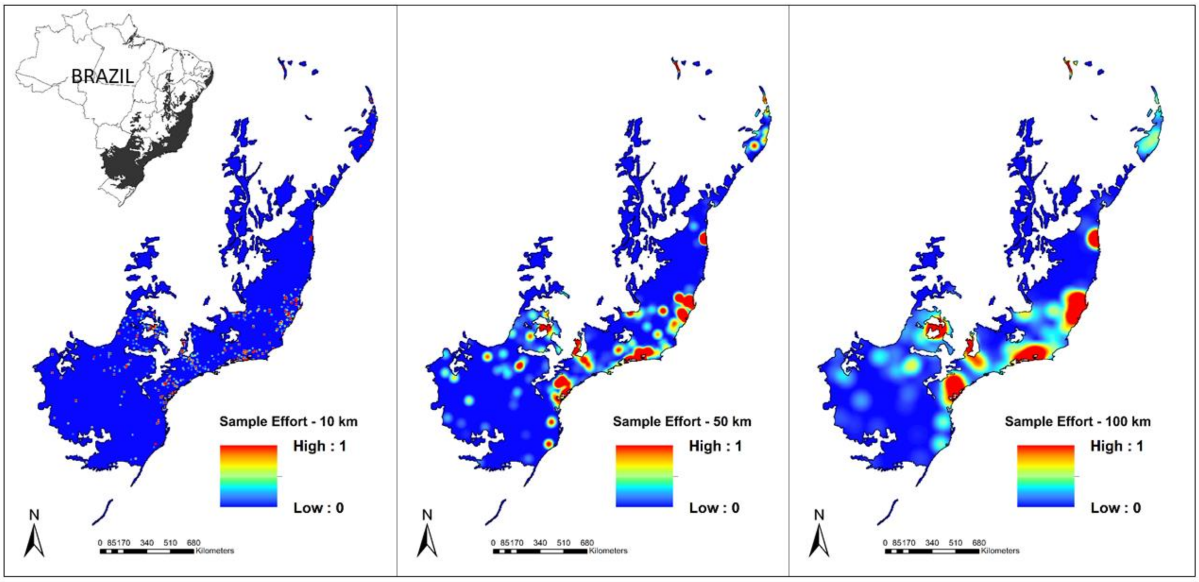


Fig. 4. Maps resulting from the sampling effort analysis for bats in the Atlantic Forest, with influence areas of 10 km², 50 km² and 100 km². The sampling effort index ranges from 0 (no effort employed on the spot) to 1 (locations with the highest employed sampling effort).

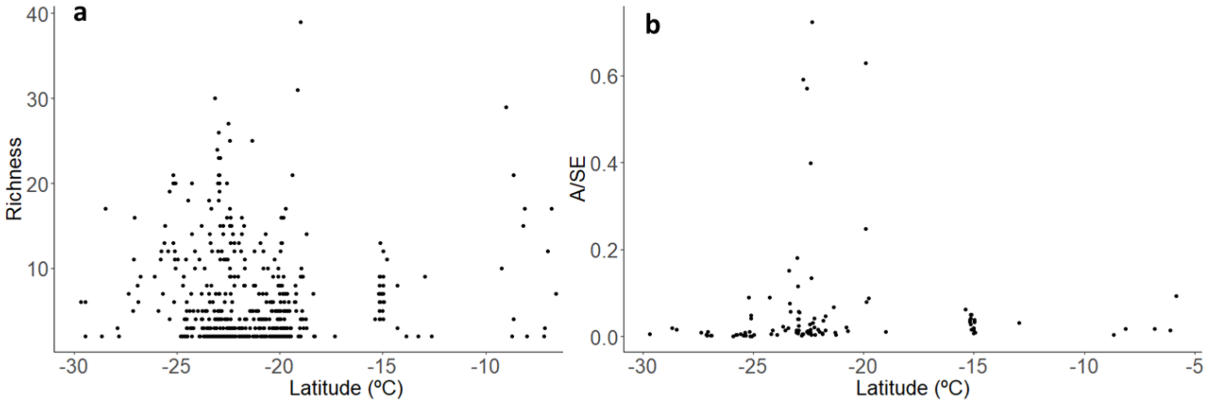


Fig. 5. Distribution of richness (a) and abundance (b; represented by the sum of the abundance index controlled by the sampling effort for each georeferenced location “A / SE sum”) of bats in the Atlantic Forest by latitude (georeferenced occurrence locations). The richness was calculated based on the total matrix of 59 species in 535 georeferenced sites. The abundance is represented by the sum of the abundance index controlled by the sampling effort for each georeferenced location “A / SE sum”, and was calculated from the matrix with data of abundance controlled by the sampling effort (“A / SE”), with a total of 58 species in 133 georeferenced sites.

5.4. Discussion

This research is the first to evaluate bat distribution for the Atlantic Forest and it has demonstrated that the biome´s central region is the only congruence area for the distribution of 98.3% of species included in this study. In fact, it represents 60.20% of bat species occurring in the Atlantic Forest and listed by Muylaert et al., (2017), and 32,41% of bat species known in Brazil (based on the list of Nogueira et al., 2018). Although five bat species with restricted range may be found in other biomes (Table 1A in pag. 148), in the Atlantic Forest they are concentrated within this congruence area. Two species belong to the same genus (*Micronycteris*) and *Dryadonycteris capixaba* (Nogueira, Lima, Peracchi & Simmons, 2012). *Dryadonycteris capixaba* is an endemic species to Brazil, it has been recently described and its conservation status has not yet been accessed (Global assessment - IUCN, 2020; National assessment - ICMBio/MMA, 2018).

Despite the Atlantic Forest not being sufficiently sampled for bats, our analysis on sampling effort (Fig. 4) and corroboration of congruence area by other studies prove that our result is not a mere outcome of the sampling effort. The Atlantic Forest center, covered by Bahia´s coastal and interior ecoregions (Olson et al., 2001) is pinpointed as an endemic and priority area for the conservation of different taxa, such as amphibians, reptiles, arthropods (Sigrist; Carvalho, 2008; Carnaval et al., 2014; Campos; Lourenço-De-Moraes, 2017), birds and mammals (Ceballos; Ehrlich, 2006), besides being acknowledged as a forest refuge (Carnaval; Moritz, 2008; Costa et al., 2018). However, there are other areas throughout the Atlantic Forest for these taxa, especially in the state of Pernambuco and in the Serra do Mar. Models of bat distribution developed for the entire Brazilian area (Delgado-Jaramillo et al., 2020) indicates that Pernambuco area has the greatest richness, whereas Serra do Mar region has the greatest endemism. We emphasize that this area is the only one where distribution bands overlaps for more than half of the bat species of the entire Atlantic Forest (Muylaert et al., 2017). Either for species with their distribution centers coinciding with congruence areas as for species whose congruence area represents one of its distribution limits which extend towards the far south or north of the Atlantic Forest (see distribution maps of species in pag. 127).

This central trend for greater richness and species restriction in the middle latitudes has already been demonstrated at a larger scale for New World bats, where the inter-tropical zone proved to be one of the richest and most endemic regions (Arita et al., 2014). The Atlantic Forest is a biome with a broad range in latitude (featuring a 30-degree interval) and it is known that latitude predicts environmental (climatic) gradients (Willig et al., 2003; Soininen et al., 2018). These gradients affect bat distribution patterns with the Bahia’s ecoregions (the biome´s middle latitudes), especially its coastal ecoregion, ~~to be one of~~being the richest in all of the Atlantic Forest biome regarding bat species (families Phyllostomidae, Noctilionidae, Furipteridae, Thyropteridae and Natalidae) (Batista et al., 2020). Our approach demonstrates that this central region is not only the richest zone but also represents a congruence area with the greatest diversity and number of restricted species. Although not all species have the same behavior (see maps on species distribution in Supplementary Material 1), the general distribution of abundance follows the same richness pattern. The "A/SE" index decreases from the center of the Atlantic Forest, mainly towards the biome´s far southern region (Fig. 4), which is highly nested to the central and the northern segments of the Atlantic Forest, regarding bat richness (Batista et al., 2020). Consequently, bat species respond to favorable environmental conditions which, for most of them, decrease from the center to the biome´s extremes, especially the far southern segment where low temperature climates are more hostile and species ecological requirements are harder to attain (Batista et al., 2020).

Besides taxonomic diversity, the congruence area analyzed comprises species with diversified life history traits including all feeding-habit guilds of bats (frugivore, nectarivore, insectivore, carnivore, omnivore, piscivore and hematophagous species) (Table 1A in pag. 148). This suggests an area rich in biotic resources, with interaction networks between different *taxa*, suggesting high diversity of functional features and ecosystem services. Although it is still necessary to test the phylogenetic diversity of bats for the Atlantic Forest, our congruence area corroborates with one of the refuge areas of the Atlantic Forest (Carnaval; Moritz, 2008; Carnaval et al., 2009; Costa et al., 2018). A refuge area is a zone of climatic stability which permitted, during interglacial periods, an accumulation of richness, endemism and genetic diversity (Carnaval; Moritz, 2008; Carnaval et al., 2009).

In contradiction with the high bat biodiversity represented by the congruence area, this area is currently one of the regions with the lowest protected area coverage rates for the biome (Fig. 2). Most PAs in the Atlantic Forest are concentrated in the south region, especially in the Serra do Mar (Sobral-Souza et al., 2018). Although 58 out of 59 bat species from this study occur in PAs throughout the Atlantic Forest, these species scantily occur in PAs within the congruence area. It should be emphasized that five bat species (*Lonchorhina aurita*, *Macrophyllum macrophyllum*, *Phylloderma stenops*, *Thyroptera tricolor* and *Vampyrodes caraccioli*) failed to have any record in legally PAs within the congruence area, and *L. aurita* is threatened in Brazil (ICMBio/MMA, 2018). Furthermore, the congruence area in this study lies within one of the regions with the smallest number of forest remnants and with the highest anthropogenic impacts, precisely within the Brazilian economic hub (Ribeiro et al., 2009). This region is being strongly impacted by mining (Garcia et al., 2016), by the lack of proper evaluation of long-term impacts (Fernandes et al. 2016) and by precarious regulations (through legislation) of mining activities. For example, the rupture of iron residue dams in Mariana (Neves et al. 2016) and Brumadinho (Cionek et al. 2019), in the state of Minas Gerais, has been perhaps, one of the worst environmental disasters in the history of Brazil. It was estimated that environmental and material losses caused by the Mariana disaster alone sums more than 20 billion dollars (Fernandes et al. 2016).

Therefore, under conservation perspective, the area analyzed in this study indicates one of the key-regions for the establishment of PAs for the protection of diversity and ecosystems services of the Atlantic Forest. It represents an area with critical sites for the conservation of different taxa; predictions on how bats would respond to climatic changes, with loss of adequate environmental areas within the Brazilian savanna suggests that species would mainly move towards the southeastern region, to the state of Minas Gerais (Aguiar et al., 2016) (this is precisely the ecotone region between savanna and the Atlantic Forest where the Bahia ecoregions and the reported congruence areas are found); and finally, it is a poorly protected area and highly impacted by human activities. New PAs should be established together with the expanstion of existing Pas, where investments should applied on reforestation techniques towards a more “biodiversity friendly” landscape by connecting secondary forest fragments to PAs (Melo et al., 2013). It is important to note that our area of congruence is one of the areas that deserve special attention when planning the zoning of priortitary areas for conservation, but not the only one. Other sites along the biome are also critical for conserving the diversity of other taxa (Ceballos; Ehrlich, 2006; Sigrist; Carvalho, 2008; Carnaval et al., 2014; Campos; Lourenço-De-Moraes, 2017); however, the biome center is always indicated as one of those sites.

Since bats are a highly diversified group, using them as a model in the search for areas with high taxonomic diversity and ecosystem services may be useful to pinpoint areas where conservation efforts should be primarily focused upon. However, our results omit other important areas for conservation, both for bats and for other taxa, and this may be due to the fact that areas of endemism are analysis scale dependent (Daru et al., 2020). *Noctilio albiventris*, for example, is not present in our congruence area, since its distribution records for the Atlantic Forest are restricted to the south of the biome. This makes it necessary for the analysis to be repeated at other scales, for example, by subdividing (north, center and south) the Atlantic Forest. This should allow a more precise answer to the question about using bats and endemic area models to indicate PAs. Nvertheless, our study was able to find an important critical area presenting a deficit in the number and size of PAs. Therefore, we emphasize the urgency for the establishment of PAs within coastal and interior regions of the state of Bahia. As we stand in front of an economic crisis scene in a post-Covid-19 pandemic, where conservation financing will not be a priority, we should shed light in the opportunity brought by this pandemic, highlighting the relationships between conservation and environmental health, coupled to human health and well-being (Corlett el al 2020). It is primordial to increase pressure on public managers and decision-makers to strengthen conservation regulations, providing support for PAs (Corlett et al., 2020). Our analysis, therefore, results in an efficient strategy for the ecological-economic planning of the Atlantic Forest PAs, implying that efforts for the conservation of biodiversity and for the maintenance of ecosystem services will be more efficient in an increase in the cost-benefit relationship in the establishment of PAs.

Acknowledgements

The authors would like to thank Programa de Pós Graduação da Universidade Estadual de Londrina for logistic support. We would also like to thanks Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) that financed part of the study (Finance code 001) and Fundação Araucária for providing a scholarship to CB Batista (Edital 20/2015).

Funding: This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior [Finance code 001]; and the Fundação Araucária [Edital 20/2015].

References

Aguiar, L. M. S., Bernard, E., Ribeiro, V., Machado, R. B., Jones, G. 2016. Should I stay or should I go? Climate change effects on the future of Neotropical savannah bats. Global Ecology and Conservation. 5, 22–33. DOI: 10.1016/j.gecco.2015.11.011

Arita, H. T., Vargas-Barón, J., Villalobos, F. 2014. Latitudinal gradients of genus richness and endemism and the diversification of New World bats. Ecography. n/a–n/a. DOI:10.1111/ecog.00720

Asaad, I., Lundquist, C. J., Erdmann, M. V., Costello, M. J. 2017. Ecological criteria to identify areas for biodiversity conservation. Biological Conservation. 213, 309–316. DOI:

10.1016/j.biocon.2016.10.007

Batista, C. B., Lima, I. P., Lima, M. R. 2020. Beta diversity patterns of bats in the Atlantic Forest: How does the scale of analysis affect the importance of spatial and environmental factors? Journal of Biogeography, 00, 1-10. DOI:10.1111/jbi.13928

Campos, B. A. T. P., Feijó, A., Brennand, P. G. de G., Percequillo, A. R. 2018. Mammals of a restinga forest in Mataraca, Paraíba, northeastern Brazil, and its affinities to restinga areas in Brazil. Biota Neotropica, 18, 1, e20170392. DOI: 10.1590/1676-0611-bn-2017-0392

Campos, F.S.; Lourenço-De-Moraes, R. 2017. Anurans from the mountain chain Serra do Mar: a critical area for amphibian conservation in the Atlantic Forest, Brazil. Herpetology Notes. 10, p. 547-560.

Cañadas, E.M.; Fenu, G.; Peñas, J.; Lorite, J.; Mattana, E.; Bacchetta, G. 2014. Hotspots within hotspots: endemic plant richness, environmental drivers, and implications for conservation. Biological Conservartion. 170, p. 282–291. DOI: https://doi.org/10.1016/j.biocon.2013.12.007

Carnaval, A.C., Moritz, C. 2008. Historical climate modelling predicts patterns of current biodiversity in the Brazilian Atlantic forest. Journal of Biogeography. 35, 1187–1201. DOI: https://doi.org/10.1111/j.1365-2699.2007.01870.x

Carnaval, A.C., Hickerson, M.J., Haddad, C.F. B., Rodrigues, M.T., Moritz, C. 2009. Stability Predicts Genetic Diversity in the Brazilian Atlantic Forest Hotspot. Science. 323(5915), 785–789. DOI: 10.1126/science.1166955

Carnaval, A. C., Waltari, E., Rodrigues, M. T., Rosauer, D., VanDerWal, J., Damasceno, R... Moritz, C. 2014. Prediction of phylogeographic endemism in an environmentally complex biome. Proceedings Royal Society Biological Sciences. 281, 14–61. DOI: https://doi.org/10.1098/rspb.2014.1461

Castuera-Oliveira, L., Oliveira-Filho, A.T., Eisenlohr, P. V. 2020. Emerging hotspots of tree richness in Brazil. Acta Botanica Brasilica. 34(1), 117-134. DOI: https://dx.doi.org/10.1590/0102-33062019abb0152

Ceballos, G., Ehrlich, P.R. 2006. Global mammal distributions, biodiversity hotspots, and conservation. Proceedings of the National Academy of Sciences USA 103, 19374–19379. DOI: https://doi.org/10.1073/pnas.0609334103

CEPF. Critical Ecosystem Partnership Fund. 2016. Announcing the World's 36th Biodiversity Hotspot: The North American Coastal Plain. http://www.cepf.net/news/top_stories/Pages/Announcing-the-Worlds-36th- Biodiversity-Hotspot.aspx. (Accessed 30 April 2020).

Cionek, V.M., Alves, G. H. Z., Tófoli, R. M., Rodrigues-Filho, J. L., Dias, R. M. 2019. Brazil in the mud again: lessons not learned from Mariana dam collapse. Biodiversity and Conservation. 28, 1935–1938. DOI: https://doi.org/10.1007/s10531-019-01762-3

Costa, G.C., Hampe, A., Ledru, M.-P., Martinez, P.A., Mazzochini, G.G., Shepard, D.B., Werneck, F.P., Moritz, C., Carnaval, A.C. 2018. Biome stability in South America over the last 30 kyr: Inferences from long-term vegetation dynamics and habitat modelling. Global Ecology and Biogeography. 27, 285–297. DOI: https://doi.org/10.1111/geb.12694

Corlett, R. T., Primack, R. B., Devictor, V., Maas, B., Goswami, V. R., Bates, A. E., … Roth, R. 2020. Impacts of the coronavirus pandemic on biodiversity conservation. Biological Conservation. 108571. DOI:10.1016/j.biocon.2020.108571

Daru, B. H., Farooq, H., Antonelli, A., Faurby, S. 2020. Endemism patterns are scale dependent. Nature Communications, 11, 1. DOI:10.1038/s41467-020-15921-6

Delgado-Jaramillo; M., Aguiar, L. M. S., Machado, R. B., Bernard, E. 2020. Assessing the distribution of a species-rich group in a continental-sized megadiverse country: Bats in Brazil. Diversity and Distributions. 00, 1–12. DOI: 10.1111/ddi.13043

Di Minin, E., Soutullo, A., Bartesaghi, L., Rios, M., Szephegyi, M. N., Moilanen, A. 2017. Integrating biodiversity, ecosystem services and socio-economic data to identify priority areas and landowners for conservation actions at the national scale. Biological Conservation. 206, 56–64. DOI: https://doi.org/10.1016/j.biocon.2016.11.037

Dirzo, R., Young, H.S., Galetti, M., Ceballos, G., Isaac, N.J.B., Collen, B. 2014. Defaunation in the Anthropocene. Science. 345, 6195, 401–406.

Fernandes, G.W., Goulart, F.F., Ranieri, B.D., Coelho, M.S., Dales, K., Boesche, N., … Soares-Filho, B. 2016. Deep into the mud: ecological and socio-economic impacts of the dam breach in Mariana, Brazil. Natureza & Conservação. 14(2), 35–45. DOI:10.1016/j.ncon.2016.10.003

Garcia, L. C., Ribeiro, D. B., de Oliveira Roque, F., Ochoa-Quintero, J. M., Laurance, W. F. 2016. Brazil’s worst mining disaster: Corporations must be compelled to pay the actual environmental costs. Ecological Applications. 27(1), 5–9. DOI: 10.1002/eap.1461

Harold, A. S., Mooi, R. D. 1994. Areas of Endemism: Definition and Recognition Criteria. Systematic Biology. 43(2), 261–266. DOI: 10.1093/sysbio/43.2.261

Herkt, K. M. B., Barnikel, G., Skidmore, A. K., Fahr, J. 2016. A high-resolution model of bat diversity and endemism for continental Africa. Ecological Modelling. 320, 9–28. DOI: 10.1016/j.ecolmodel.2015.09.009

Hortal, J. 2008. Uncertainty and the measurement of terrestrial biodiversity gradients. Journal of Biogeography. 35(8): 1335–1336. DOI: 10.1111/j.1365-2699.2008.01955.x

Hortal, J.; Lobo, J. M.; Jiménez-Valverde, A. 2007. Limitations of Biodiversity Databases: Case Study on Seed-Plant Diversity in Tenerife, Canary Islands. Conservation Biology, 21(3): 853–863. DOI: 10.1111/j.1523-1739.2007.00686.x

Hsieh TC, Ma KH, and Chao A. 2019. iNEXT: iNterpolation and EXTrapolation for species diversity. R package version 2.0.19 URL: http://chao.stat.nthu.edu.tw/blog/software-download/ (Accessed 30 April 2020).

ICMBio/MMA. 2018. Livro Vermelho da Fauna Brasileira Ameaçada de Extinção: Volume I / -- 1. ed. -- Brasília, DF:. 492 p.

IUCN 2020. The IUCN Red List of Threatened Species. Version 2020-1. https://www.iucnredlist.org. (Accessed 19 March 2020).

Jenkins, C. N.; Pimm, S. L. 2006. Definindo prioridades de conservação em um Hotspot de biodiversidade global. In: ROCHA; C. F. D. et al. (Org.). Biologia da conservação: essências. São Carlos: RiMa. cap. 2, p. 41-52.

Johnson, C., Balmford, A., Brook, B., Buettel, J., Galetti, M., Guangchun, L.,

& Wilmshurst, J. 2017. Biodiversity losses and conservation responses in the Anthropocene. Science. 356 (6335), 270-275. DOI: https://doi.org/10.1126/science.aam9317

Kalka, M. B., Smith, A. R., Kalko, E. K. V. 2008. Bats Limit Arthropods and Herbivory in a Tropical Forest. Science. 320(5872), 71–71. DOI: 10.1126/science.1153352

Kindt R., Coe R. 2005. Tree diversity analysis. A manual and software for common statistical methods for ecological and biodiversity studies. World Agroforestry Centre (ICRAF), Nairobi. ISBN 92-9059-179-X.

Melo et al. 2013. On the hope for biodiversity-friendly tropical landscapes. Trends in Ecology & Evolution. 28, 462-468. DOI: 10.1016/j.tree.2013.01.001

Ministério do Meio Ambiente. MMA. 2017. https://www.mma.gov.br/publicacoes/biomas/category/63-mata-atlantica.html (Accessed 30 April 2020)

Muylaert, R.D.L., Stevens, R.D., Esbérard, C.E.L., Mello, M.A.R., Garbino, G.S.T., Varzinczak, L.H., ... Galetti, M. 2017. ATLANTIC BATS: a data set of bat communities from the Atlantic Forests of South America. Ecology. 98(12), 3227. DOI: https://doi.org/10.1002/ecy.2007

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A.B., Kent, J. 2000. Biodiversity hotspots for conservation priorities. Nature. 403, 853-858. DOI: 10.1038/35002501

Nelson, B. W., Ferreira, C. A. C., da Silva, M. F., Kawasaki, M. L. 1990. Endemism centres, refugia and botanical collection density in Brazilian Amazonia. Nature. 345(6277), 714–716. DOI: 10.1038/345714a0

Neves, A. C. de O., Nunes, F. P., de Carvalho, F. A., Fernandes, G. W. 2016. Neglect of ecosystems services by mining, and the worst environmental disaster in Brazil. Natureza & Conservação. 14(1), 24–27. DOI: 10.1016/j.ncon.2016.03.002

Nogueira, M. R., Pol, A., Monteiro, L. R., Peracchi, A.L. 2008. First record of Miller's mastiff bat, Molossus pretiosus (Mammalia: Chiroptera), from the Brazilian Caatinga. Chiroptera Neotropical. 14 (1), 346–353.

Nogueira, M. R., Pol, A., & Peracchi, A.L. 1999. New records of bats from Brazil with a list of additional species for the chiropteran fauna of the state of Acre, western Amazon basin. Mammalia. 63 (3), 363–368.

Nogueira M.R., I.P. Lima, G.S.T. Garbino, R. Moratelli, V.C. Tavares, R. Gregorin, and A.L. Peracchi. 2018. Updated checklist of Brazilian bats: version 2018.1. Comitê da Lista de Morcegos do Brasil—CLMB. Sociedade Brasileira para o Estudo de Quirópteros (Sbeq).<http://www.sbeq.net/updatelist> (Accessed 16 February 2020).

Noss, R.F., Platt, W.J., Sorrie, B.A., Weakley, A.S., Means, D.B., Costanza, J., Peet, R.K. 2015. How global biodiversity hotspots may go unrecognized: lessons from the North American Coastal Plain. Diversity and Distributions. 21, 236-244. DOI: https://doi.org/10.1111/ddi.12278

Nunes, H., Rocha, P.A., Sales, J., Rocha, F.L, Cordeiro-Estrela, P. 2018. First record of *Uroderma magnirostrum* Davis, 1968 (Chiroptera: Phyllostomidae) in the northeastern Atlantic Forest of Brazil. Oecologia Australis. 22, 3: 312–319. DOI: 10.4257/oeco.2018.2203.10

Oliveira, U. 2018. Guia completo de uso de BioDinamica. DOI: 10.13140/RG.2.2.26705.17765

Oliveira, U., Brescovit, A. D., Santos, A. J. 2015. Delimiting Areas of Endemism through Kernel Interpolation. PLOS ONE. 10(1), e0116673. DOI: https://doi.org/10.1371/journal.pone.0116673

Oliveira, U., Soares-Filho, B. S., Santos, A. J., Paglia, A. P., Brescovit, A. D., de Carvalho, C. J. B., … Ferro, V. G. 2019. Modelling Highly Biodiverse Areas in Brazil. Scientific Reports. 9(1), 6355. DOI: 10.1038/s41598-019-42881-9

Oliveira, U., Vasconcelos, M. F., Santos, A. J. 2017. Biogeography of Amazon birds: rivers limit species composition, but not areas of endemism. Scientific Reports. 7(1), 2992. DOI: 10.1038/s41598-017-03098-w

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N… Kenneth, R. K. 2001. Terrestrial Ecoregions of the World: A New Map of Life on Earth. BioScience. 51(11), 933-938. DOI: https://doi.org/10.1641/0006-

3568(2001)051[0933:TEOTWA]2.0.CO;2

Pedroso-Fidelis, G. dos S., Farias, H. R., Mastella, G. A., Boufleur-Niekraszewicz, L. A., Dias, J. F., Alves, M. C., … Pinho, R. A. 2020. Pulmonary oxidative stress in wild bats exposed to coal dust: A model to evaluate the impact of coal mining on health. Ecotoxicology and Environmental Safety. 191, 110211. DOI: https://doi.org/10.1016/j.ecoenv.2020.110211

Ponder, W. F., Carter, G. A., Flemons, P., Chapman, R. R. 2001. Evaluation of Museum Collection Data for Use in Biodiversity Assessment. Conservation Biology. 15(3), 648–657. DOI: 10.1046/j.1523-1739.2001.015003648.x

Ribeiro, M. C., Metzger, J. P., Martensen, A. C., Ponzoni, F. J., Hirota, M. M. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation. 142(6), 1141–1153. DOI: 10.1016/j.biocon.2009.02.021

Sasaki, K., Lesbarrères, D., Beaulieu, C. T., Watson, G., Litzgus, J. 2016. Effects of a mining-altered environment on individual fitness of amphibians and reptiles. Ecosphere. 7(6), e01360. DOI: https://doi.org/10.1002/ecs2.1360

Sigrist, M.S.; Carvalho, C.J.B. 2008. Detection of areas of endemism on two spatial scales using Parsimony Analysis of Endemicity (PAE): the Neotropical region and the Atlantic Forest. Biota Neotropica. 8(4), 33-42. DOI: https://doi.org/10.1590/S1676-06032008000400002

Simmons, N. B. Order Chiroptera. 2005. In: Wilson, D.E.; Reeder, D.M. (eds.). Mammal species of the World: a taxonomic and geographic reference. Third Edition, Volume 1, Johns Hopkins University Press, p. 312-529.

Sobral-Souza, T., Vancine, M. H., Ribeiro, M. C., Lima-Ribeiro, M. S. 2018. Efficiency of protected areas in Amazon and Atlantic Forest conservation: A spatio-temporal view. Acta Oecologica. 87, 1–7. DOI: 10.1016/j.actao.2018.01.001

Soininen, J., Wang, J., Heino, J. 2018. A meta-analysis of nestedness and turnover components of beta diversity across organisms and ecosystems. Global Ecology and Biogeography. 27(1), 1-14. DOI: https://doi.org/10.1111/geb.12660

Souza, M.A.N., Langguth, A., Gimenez, E.A. 2004. Mamíferos dos Brejos de Altitude da Paraíba e Pernambuco. In Brejos de Altitude em Pernambuco e Paraíba, História Natural, Ecologia e Conservação (K.C. Porto, J.J.P. Cabral, M. Tabarelli, eds.). Ministério do Meio Ambiente, Brasília, (série Biodiversidade, n. 9), p.229-254.

Stokland, J. N., Halvorsen, R., Støa, B. 2011. Species distribution modelling—Effect of design and sample size of pseudo-absence observations. Ecological Modelling. 222(11), 1800–1809. DOI: 10.1016/j.ecolmodel.2011.02.025

Trajano, E. 1984. Ecologia de populações de morcegos cavernícolas em uma região cárstica do sudeste do Brasil. Revista Brasileira de Zoologia. 2(5), 255-320.

Utina, R., Katili, A.S. 2014, Inventory of Water Bird Species Which Accumulate Mercury from Mining Waste in Coastal Area North Gorontalo Regency, Indonesia, Int. J. of Waste Resources. 4(1). DOI: 10.4172/2252-5211.1000132

Vargas-Mena, J. C., Alves-Pereira, K., Barros, M. A. S., Barbier, E., Cordero-Schmidt, E., Lima, S. M. Q., … Venticinque, E. M. 2018. The bats of Rio Grande do Norte state, northeastern Brazil. Biota Neotropica, 18, 2. DOI:10.1590/1676-0611-bn-2017-0417

Vellend, M., Baeten, L., Becker-Scarpitta, A., Boucher-Lalonde, V., Mccune, J.L.; Messier, J., Myers-Smith I.H., Sax, D.F. 2017. Plant Biodiversity Change Across Scales During the Anthropocene. Annual Review of Plant Biology. 68, 1, 563–586. DOI: 10.1146/annurev-arplant-042916-040949

Werneck, M.S., Sobral, M.E.G., Rocha, C.T.V., Landau, E.C., Stehmann, J.R., Wickham, H. 2011. Distribution and Endemism of Angiosperms in the Atlantic Forest. Natureza & Conservação. 9(2), 188-193. DOI: 10.4322/natcon.2011.024

Wickham, H.2016. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.https://ggplot2.tidyverse.org (Accessed 30 April 2020)

Williams, K.J., Ford, A., Rosauer, D.F., De Silva, N., Mittermeier, R.A., Bruce, C., Larsen, F.W., Margules, C. 2011. Forests of East Australia: The 35th Biodiversity Hotspot. In: Zachos FE, Habel JC (eds) Biodiversity Hotspots: Distribution and Protection of Priority Conservation Areas. Springer-Verlag, Berlin, pp 295-310.

Willig, M. R., Kaufman, D. M., Stevens, R. D. 2003. Latitudinal gradients of biodiversity: Pattern, process, scale, and synthesis. Annual Review of Ecology Evolution and Systematics. 34, 273–309. DOI: https://doi.org/10.1146/annurev.ecolsys.34.012103.144032

Zocche, J. J., Leffa, D. D., Damiani, A. P., Carvalho, F., Mendonça, R.A., dos Santos, C. E. I., … de Andrade, V. M. 2010. Heavy metals and DNA damage in blood cells of insectivore bats in coal mining areas of Catarinense coal basin, Brazil. Environmental Research. 110(7), 684–691. DOI: 10.1016/j.envres.2010.06.003

6. CONCLUSÃO GERAL

Esta tese foi desenvolvida com base em revisões e análises de dados cuidadosas e criteriosas, permitindo o uso de seus resultados em trabalhos futuros ou para tomas de decisões em conservação. O capítulo 1, fornece um confiável banco de dados de ocorrência de morcegos na região de Londrina/PR e aponta as possíveis lacunas de amostragem. Dessa forma, pode servir de base para estudos ecológicos mais complexos e como orientação para que futuros projetos desenvolvidos na região direcionem novos esforços de amostragem onde ainda existem lacunas de conhecimento. Ainda, demonstra a importância da conservação de vários fragmentos florestais de diferentes tipos (ex. UC’s, reservas legais e áreas verdes urbanas) na paisagem para manter a diversidade de morcegos na região de Londrina. O capítulo 2, conseguiu explicar como ocorre a variação na composição das comunidades de morcegos em toda a Mata Atlântica, indicando a relação da riqueza com fatores climáticos e distância geográfica, associados aos gradientes latitudinais e longitudinais do bioma. Essa complexa variação demonstrou a importância de particionar a diversidade beta (substituição e aninhamento) e de analisá-la em diferentes escalas para entender como a variação ambiental no espaço geográfico influencia os padrões de distribuição das espécies. Os resultados desse capítulo têm implicações práticas importantes pois ajuda a prever como as mudanças ambientais podem interferir na distribuição das espécies, uma vez que indicam a importância de fatores ambientais como preditores da composição das espécies de morcegos. Sendo que essas preditores ambientais devem ser levados em consideração nos estudos biogeográficos, ecológicos e de conservação, inclusive na conservação prática. O capítulo 3, mostrou que o uso da análise de área de endemismo com morcegos como modelo, pode possibilitar encontrar uma região chave para investir em conservação e salvaguardar os atributos de diversidade e serviços ecossistêmicos da Mata Atlântica. Além disso, o fato de a área de congruência (de 58 das 59 espécies de morcegos utilizadas na análise) estar localizada em uma zona de estabilidade climática, mas com alto impacto antrópico e pouca proteção eficiente, indica a urgência na criação de UCs dentro das regiões da costa e interior da Bahia. Dessa forma, a análise desse capítulo resulta em uma estratégia mais eficaz no planejamento de zoneamento ecológico-econômico das áreas prioritárias na Mata Atlântica, implicando que os esforços para a conservação da biodiversidade e manutenção dos serviços ecossistêmicos serão mais eficientes em cenários climáticos futuros, aumentando a relação custo-benefício na criação de UCs.

APÊNDICES

APÊNDICE A

Material suplementar do Capítulo 1. O material encontra-se nas normas do periódico “Neotropical Biology and Conservation”.

SUPPORTING INFORMATION

Table 1. References used to provide data on bat occurrence records for the Londrina region, Brazil, with their respective period of capture. Captured sites were: Parque Estadual Mata dos Godoy (PEMG); Parque Municipal Arthur Thomas (PMAT); campus of the Universidade Estadual de Londrina (UEL) (including Horto Florestal); Jardim Botânico; Legal Reserves within private farmland (Mata do Bule, Fazenda Imbaúva, Chácara Kanashiro, Chácara Vitória and Fazenda Regina); and the metropolitan region of Londrina (including banks of the Igapó Lake; and other green areas in the municipality and human building, both sites without georeferenced exact indication).

Publications	**Place of capture**	**Period of capture**	**Source**
Sekiama (1992)	PEMG; PMAT; UEL	1982 – 1993; 1989 – 1992.	Undergraduate dissertation.
Muller and Reis (1992)	PEMG; PMAT	1989 - 1992	Published article; data were retrieved from field notes since the publication does not give a complete list of captured species.
Reis *et al.* (1993)	PEMG; PMAT; UEL; Fazenda Imbaúva; Chácara Kanashiro	1982 a 1983	Published article.
Lima (1994)	UEL	1993	Undergraduate dissertation and field notebook to supplement information.

Reis and Muller (1995)	PEMG; PMAT; UEL; Fazenda Regina	1989 - 1992	Published article.
Sekiama (1996)	PEMG	1993 - 1994	Masters Dissertation.
Lima, I. P.	UEL	1998	Non-published data; field notes by researcher from the mammal ecology laboratory of the UEL.
Reis *et al.* (2000)	PEMG	1993 - 1994	Published article.
Félix *et al.* (2001)	PMAT; UEL	1999 - 2000	Published article: data retrieved from field notebook to supplement information.
Reis *et al.* (2006)	UEL and other sites in metropolitan Londrina region	1998 - 1999	Published article; however, data were retrieved from field notebook. The article failed to give the exact site of capture of each species.
Reis *et al.* (2012a)	PEMG; PMAT; UEL; Fazenda Regina; Chácara Vitória; and other sites in metropolitan Londrina region	1982 - 2012	Published article.

Reis *et al*. (2012b)	UEL	2008 - 2009	Published article.
Fregonezi (2012)	PEMG	2011	Master Dissertation.
Batista, C. B.	PEMG	2013 - 2014	Master Dissertation data, retrieved from field notebook.
Batista, C. B.	PEMG; UEL;	2015 - 2016	Non-published data; field notes by researcher from the Laboratório de Ecologia de Mamíferos of the UEL.
Batista *et al*., 2018	Mata do Bule and Jardim Botânico de Londrina	2015 - 2016	Published article.

Table 2. List of species reported for the region of Londrina, PR, Brazil, in published articles and unpublished data included in this study. Preferential food: C- Carnivorous; I – Insectivorous; H – Hematophagous; O - Omnivorous; N – Nectarivorous; F – Frugivorous; P - Piscivorous.. The capture sites are: two Protected Areas in the region – Parque Estadual Mata dos Godoy (PEMG) and Parque Municipal Arthur Thomas (PMAT) -; the Legal Reserves (Mata do Bule, Fazenda Imbaúva, Chácara Kanashiro, Chácara Vitória and Fazenda Regina); and the metropolitan region of Londrina, which includes the campus of the Universidade Estadual de Londrina (UEL) and its Horto Florestal; the Jardim Botânico de Londrina; banks of the Igapó Lake; other green areas in the municipality (non-identified valleys) and human building (sites without exact indication). The threat categories were based on a regional (RE) (Margarido and Braga, 2004) National (NA) (ICMBio, 2014) and international (IN) (IUCN) list and are: LC- Least concern; VU - Vulnerable; CR - Critically Endangered; DD - Data deficient; and NT - Near threatened.

Specie	**Guild**	**Conservation status**	**Protected Areas**		**Other sites**
			PEMG	**PMAT**	
Family Phyllostomidae **Subfamily Micronycterinae**					
Micronycteris microtis Miller, 1898	I	LC (NA; IN)	X	X	Fazenda Regina; Jardim Botânico
Subfamily Desmodontinae					

Desmodus rotundus (É Geoffroy, 1810)	H	LC (NA; IN)	X		Fazenda Regina
Diaemus youngii (Jentink, 1893)	H	LC (NA; IN); CR (RE)	X		
Diphylla ecaudata (Spix, 1823)	H	LC (NA; IN); VU (RE)	X		
Subfamily Phyllostominae					
Chrotopterus auritus (Peters, 1856)	C	LC (NA; IN); VU (RE)	X	X	Fazenda Regina;
Phyllostomus discolor (Wagner, 1843)	O	LC (NA; IN)			Sites without exact indication, but sampling included UEL, Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Phyllostomus hastatus (Pallas, 1767)	O	LC (NA; IN)		X	UEL; Jardim Botânico
Subfamily Glossophaginae					
Anoura caudifer (É. Geoffroy, 1818)	N	LC (NA; IN)	X	X	Jardim Botânico
Glossophaga soricina (Pallas, 1766)	N	LC (NA; IN)	X		UEL

Subfamily Carolliinae					
Carollia perspicillata (Linnaeus, 1758)	F	LC (NA; IN)	X	X	Fazenda Regina; Mata do Bule; UEL; Jardim Botânico and other sites without exact indication, but sampling included Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Subfamily Stenodermatinae					
Artibeus fimbriatus Gray, 1838	F	LC (NA; IN)	X	X	Mata do Bule; UEL; Jardim Botânico and other sites without exact indication, but sampling included Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Artibeus lituratus (Olfers, 1818)	F	LC (NA; IN)	X	X	Fazenda Imbaúva; Fazenda Regina; Chácara Kanashiro; Mata do Bule; UEL; Jardim Botânico; non-identified valleys ; Human buildings (includes roof for houses and buildings, manholes, crevices and others)

Artibeus obscurus (Schinz, 1821)	F	LC (NA; IN)	X		Sites without exact indication, but sampling included UEL, Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Artibeus planirostris (Spix, 1823)	F	LC (NA; IN)	X	X	Mata do Bule
Chiroderma doriae Thomas, 1891	F	LC (NA; IN); VU (RE)			Fazenda Regina
Chiroderma villosum Peters, 1860	F	LC (NA; IN); DD (RE)			Sites without exact indication, but sampling included UEL, Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Platyrrhinus lineatus (É. Geoffroy, 1810)	F	LC (NA; IN)	X	X	Fazenda Regina; UEL; Jardim Botânico and other sites without exact indication, but sampling included UEL, Chácara Vitória, banks of the Igapó Lake and non-identified valleys; Human buildings (includes roof for houses and buildings, manholes, crevices and others)

Pygoderma bilabiatum (Wagner, 1843)	F	LC (NA; IN)	X	X	Fazenda Regina; Mata do Bule; UEL; Jardim Botânico and other sites without exact indication, but sampling included UEL, Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Sturnira lilium (É. Geoffroy, 1810)	F	LC (NA; IN)	X	X	Fazenda Regina; Chácara Kanashiro; Mata do Bule; UEL; Jardim Botânico and other sites without exact indication, but sampling included Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Vampyressa pusilla (Wagner, 1843)	F	LC (NA); DD (IN)	X	X	UEL
Family Noctilionidae					
Noctilio albiventris Desmarest, 1818	I	LC (NA; IN)			banks of the Igapó Lake 23°19'34.24"S 51°10'27.43"O

Noctilio leporinus (Linnaeus, 1758)	P	LC (NA; IN)		Sites without exact indication, but sampling included UEL, Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Family Molossidae **Subfamily Molossinae**				
Eumops glaucinus (Wagner, 1843)	I	LC (NA; IN)		Human buildings (includes roof for houses and buildings, manholes, crevices and others)
Eumops perotis (Schinz, 1821)	I	LC (NA; IN)		Metropolitan region of Londrina, without exact site indication.
Cynomops abrasus (Temmick, 1827)	I	LC (NA); DD (IN)	X	UEL and other sites without exact indication, but sampling included, Chácara Vitória, banks of the Igapó Lake and non-identified valleys

Molossus molossus (Pallas, 1766)	I	LC (NA; IN)	X	UEL; Jardim botânico and other sites without exact indication, but sampling included, Chácara Vitória, banks of the Igapó Lake and non-identified valleys; Human buildings (includes roof for houses and buildings, manholes, crevices and others)
Molossus rufus É. Geoffroy, 1805	I	LC (NA; IN)	X	UEL; Jardim botânico; Human buildings (includes roof for houses and buildings, manholes, crevices and others)
Nyctinomops laticaudatus (É. Geoffroy,1805)	I	LC (NA; IN)	X	UEL; Human buildings (includes roof for houses and buildings, manholes, crevices and others)
Nyctinomops macrotis (Gray, 1840)	I	LC (NA; IN)		Human buildings (includes roof for houses and buildings, manholes, crevices and others)

Tadarida brasiliensis (I. Geoffroy, 1824)	I	LC (NA; IN)		UEL and other sites without exact indication, but sampling included, Chácara Vitória, banks of the Igapó Lake and non-identified valleys; Human buildings (includes roof for houses and buildings, manholes, crevices and others)
Family Vespertilionidae **Subfamily Vespertilioninae**				
Eptesicus brasiliensis (Desmarest, 1819)	I	LC (NA; IN)	X X	Fazenda Imbaúva; other sites without exact indication, but sampling included UEL, Chácara Vitória, banks of the Igapó Lake and non-identified valleys; Human buildings (includes roof for houses and buildings, manholes, crevices and others)

Eptesicus diminutus Osgood, 1915	I	LC (NA); DD (IN)	X	X	Mata do Bule; Jardim Botânico; UEL and other sites without exact indication, but sampling included Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Eptesicus furinalis (d'Orbigny & Gervais, 1847)	I	LC (NA; IN)	X		Mata do Bule; Jardim Botânico; UEL and other sites without exact indication, but sampling included Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Epitesicus taddei Miranda, Bernardi & Passos, 2006	I	VU (NA); DD (IN)			Sites without exact indication, but sampling included Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Rogheessa io Thomas, 1903	I	DD (NA); LC (IN)			Fazenda Regina
Histiotus velatus (I. Geoffroy, 1824)	I	LC (NA); DD (IN)	X		Human buildings (includes roof for houses and buildings, manholes, crevices and others)

Lasiurus blossevillii ([Lesson, 1826])	I	LC (NA; IN)	X	X	UEL and other sites without exact indication, but sampling included Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Lasiurus ega (Gervais, 1856)	I	LC (NA; IN)	X		Human buildings (includes roof for houses and buildings, manholes, crevices and others)
Subfamily Myotinae					
Myotis levis (I. Geoffroy, 1824)	I	LC (NA; IN)			Sites without exact indication, but sampling included UEL, Chácara Vitória, banks of the Igapó Lake and non-identified valleys
Myotis nigricans (Schinz, 1821)	I	LC (NA; IN)	X	X	Fazenda Regina; UEL and other sites without exact indication, but sampling included Chácara Vitória, banks of the Igapó Lake and non-identified valleys

Myotis ruber (É. Geoffroy, 1806)	I	LC (NA); NT -IN; DD - RE	X	X	Mata do Bule and other sites without exact indication, but sampling included Chácara Vitória, banks of the Igapó Lake and non-identified valleys
RICHNESS			**28**	**17**	**39**
Total of species in Londrina region, Paraná state			**41**		

Table 3. Information on capture environments and number of nights sampled at each site in the Londrina region (Paraná, Brazil), studied for bats since 1982. PEMG – Parque Estadual Mata dos Godoy; PMAT – Parque Municipal Arthur Thomas; UEL – Campus da Universidade Estadual de Londrina. The asterisk highlight that for the PEMG information about the capture environments is not published in any of the related articles. This information was obtained directly from researchers at the Laboratório de Ecologia de Mamíferos of the Universidade Estadual de Londrina. The references that were used to compose the species list (See in Table 1 of the manuscript) and are not in this table is because they do not have information about the capture environment within the fragment or about the sampling effort.

Site	**Capture environments**	**Number of nights sampled**	**Source**
PEMG*	Visitor trails: Trilha das Perobas and Trilha dos Catetos	12	Sekiama (1992)
	Visitor trails: Trilha das Perobas and Trilha dos Catetos	23	Muller & Reis (1992)

	Visitor trails: Trilha das Perobas and Trilha dos Catetos	23	Reis *et al.* (1993)
	Visitor trails: Trilha das Perobas and Trilha dos Catetos	24	Reis & Muller (1995)
	Visitor trails: Trilha das Perobas and Trilha dos Catetos	36	Sekiama (1996)
	Visitor trails: Trilha das Perobas and Trilha dos Catetos	12	Reis *et al.* (2000)
	Visitor trails: Trilha das Perobas and Trilha dos Catetos	48	Fregonezi (2012)
	Visitor trails: Trilha das Perobas and Trilha dos Catetos	60	Batista, C. B. (Dados não publicados da dissertação e da tese. Coletados entre 2013 e 2016)
Total capture nights	**238**		
PMAT	No informations	12	Sekiama (1992)
	No informations	23	Muller & Reis (1992)
	No informations	23	Reis *et al.* (1993)
	No informations	24	Reis & Muller (1995)
	The mist nets were spread throughout the Park; installed on visitor trails at	24	Félix *et al.* (2001)

	the edge of the fragment; on the trails inside the fragment; near the waterfall and around the lake.		
Total capture nights	**106**		
UEL	No informations	12	Sekiama (1992)
	No informations	23	Reis *et al.* (1993)
	The mist nets were spread throughout the campus da Universidade Estadual de Londrina; placed on the streets and in the groves of fruit plants.	12	Lima (1994)
	No informations	24	Reis & Muller (1995)
	The mist nets were spread throughout the campus da Universidade Estadual de Londrina; placed on the streets and in the groves of fruit plants.	2	Lima, I. P. (unpublished data)
	The mist nets were spread throughout the campus da Universidade Estadual de Londrina; placed on the streets and in the groves of fruit plants frutíferas and in the Horto Florestal.	24	Félix *et al.* (2001)
	The mist nets were spread throughout the campus da Universidade Estadual de Londrina; captures were	12	Reis *et al.* (2006)

	also made in buildings of the Center for Biological Sciences (CCB)		
	Horto Florestal	12	Reis *et al.* (2012b)
	Horto Florestal	12	Batista, C. B. (unpublished data)
Total capture nights	**133**		
Jardim Botânico	The mist nets were installed in the eastern portion of the Jardim Botânico: walking visitor's tracks; trails within the forest fragment; around the artificial lake; in the area of bamboo and fruit groves.	16	Batista *et al.*, 2018
Total capture nights	**16**		
Chácara Vitória	No informations	No informations	Reis *et al.* (2012a)
Total capture nights	**-**		
Chácara Kaneshiro	No informations	23	Reis *et al.* (1993)
Total capture nights	**23**		
Fazenda Imbaúva	No informations	23	Reis *et al.* (1993)
Total capture nights	**23**		
Fazenda Regina	No informations	24	Reis & Muller (1995)
Total capture nights	**24**		

Mata do Bule	The captures were made at random points to cover the northern, southern, eastern and western regions of the fragment. The mist-nets were installed inside trails, clearings, at the edges of the fragment and around a dam.	14	Batista *et al*., 2018
Total capture nights	**14**		
Total capture nights to Londrina region	**577**		

APÊNDICE B

Material suplementar do Capítulo 2. O material encontra-se nas normas do periódico “Journal of Biogeography”.

SUPPORTING INFORMATION

Beta diversity patterns of bats in the Atlantic Forest: How does the scale of analysis affect the importance of spatial and environmental factors?

Short running title: Beta diversity of bats in the Atlantic Forest

Carolina Blefari Batista[1]*; Isaac Passos de Lima[1]; Marcos Robalinho Lima[1]

[1] - Programa de Pós-Graduação em Ciências Biológicas; Departamento de Biologia Animal e Vegetal; Centro de Ciências Biológicas; Universidade Estadual de Londrina; 86051-970, Londrina, Brazil; Phone: (+55) 43 3371-4911

*- Corresponding Author: blefaricarol@gmail.com

APPENDIX S1

Table S1.1 List of bat species and occurrence sites (coordinates) for the Atlantic Forest ecorregions. The number represent the total number of records (occurrence site) of each specie in a specific ecoregion. The table also shows other information for the species: preferential food, occurrence biomes (Reis et al., 2017) and conservation status (IUCN, 2016). Preferential food: O/C - Omnivorous/Carnivorous; I – Insectivorous; H – Hematophagous; O - Omnivorous; N – Nectarivorous; F – Frugivorous; P - Piscivorous. Occurrence in other biomes: A – Amazon; C – Cerrado; Ca – Caatinga; P – Pantanal; Pa – Pampas. Conservation status: LC – Least Concern; DD – Data Deficient and NT – Near Threatened

				Occurrence sites in ecoregions									**Total occurrence sites**
Species	**Occurrence in other biomes**	**Preferential food**	**Conservation status**	**Alto Paraná**	**Araucaria**	**Restinga Coast**	**Bahia Coastal**	**Bahia Interior**	**Campos Rupestres**	**Pernambuco Coastal**	**Pernambuco Interior**	**Serra do Mar**	
Family Phyllostomidae													
Subfamily Micronycterinae													
Lampronycteris brachyotis (Dobson, 1879)	C and A	O/C	LC	0	0	0	2	0	0	0	0	2	4
Micronycteris hirsuta (Peters, 1869)	A	I	LC	0	0	0	6	1	0	0	0	1	8
Micronycteris megalotis (Gray, 1842)	A, C, Ca and P	I	LC	17	0	0	13	5	0	1	0	20	56
Micronycteris microtis Miller, 1898	A and C	I	LC	5	0	0	3	1	2	0	0	8	19

Micronycteris minuta (Gervais, 1856)	A, C, Ca and P	I	LC	0	0	0	2	2	0	0	1	6	11
Micronycteris schmidtorum Sanborn, 1935	A, C and Ca	I	LC	0	0	0	3	0	0	0	0	0	3
Subfamily Desmodontinae													
Desmodus rotundus (É. Geoffroy, 1810)	A, Ca, C, P and Pa	H	LC	60	8	2	30	14	3	4	0	64	186
Diaemus youngii (Jentink, 1893)	A, Ca, C and P	H	LC	10	0	2	2	0	0	0	1	7	22
Diphylla ecaudata Spix, 1823	A, Ca, C and P	H	LC	3	2	0	10	5	0	2	1	21	44
Subfamily Lonchorhininae													
Lonchorhina aurita Tomes, 1863	A, Ca, C and P	I	LC	2	0	0	0	0	0	3	0	4	9
Subfamily Phyllostominae													
Chrotopterus auritus (Peters, 1856)	A, Ca, C, P and Pa	C/I	LC	31	5	0	8	4	3	1	0	19	72
Lophostoma brasiliense Peters, 1866	A, C and Ca	I	LC	0	0	2	2	1	0	1	0	0	6
Lophostoma silvicola d'Orbigny, 1836	A, Ca, C and P	I	LC	2	0	0	1	0	0	3	1	0	7
Macrophyllum macrophyllum (Schinz, 1821)	A, C and P	I	LC	1	0	0	0	0	0	0	0	1	2

Mimon bennettii (Gray, 1838)	A, Ca, C and P	I	LC	5	2	0	4	2	1	0	0	14	28
Mimon crenulatum (É. Geoffroy, 1803)	A, Ca, C and P	I	LC	1	0	0	3	2	0	0	0	2	8
Phylloderma stenops (Peters, 1865)	A, C and P	O	LC	1	0	0	0	0	0	1	0	2	4
Phyllostomus discolor (Wagner, 1843)	A, Ca, C and P	O	LC	9	0	1	11	7	0	2	1	2	33
Phyllostomus elongatus (É. Geoffroy, 1810)	A, C and P	O	LC	0	0	0	2	0	0	2	0	0	4
Phyllostomus hastatus (Pallas, 1767)	A, Ca, C and P	O	LC	17	0	1	18	8	0	2	1	17	65
Tonatia bidens (Spix, 1823)	P, C and Ca	O	DD	5	0	0	3	2	1	1	0	25	37
Tonatia saurophila Koopman & Williams, 1951	Ca, C and A	O	LC	0	0	0	2	0	0	1	1	1	5
Trachops cirrhosus (Spix, 1823)	A, C, Ca and P	O	LC	1	1	1	17	2	0	4	2	16	44
Subfamily Glossophaginae													
Anoura caudifer (É. Geoffroy, 1818)	A, C, P and Pa	N	LC	19	2	1	1	11	2	1	0	40	77
Anoura geoffroyi Gray, 1838	A, Ca, C, P and Pa	N	LC	4	2	0	2	4	1	1	0	29	43
Dryadonycteris capixaba Nogueira, Lima, Peracchi & Simmons, 2012	Ca and C	N	DD	0	0	0	3	2	0	0	0	0	5

Glossophaga soricina (Pallas, 1766)	A, Ca, C, P and Pa	N	LC	91	1	4	30	15	1	3	1	59	206
Lichonycteris degener Miller, 1931	A	N	LC	0	0	0	1	0	0	1	0	0	2
Subfamily Lonchophyllinae													
Lonchophylla mordax Thomas, 1903	Ca	N	LC	0	0	0	10	0	0	0	0	7	17
Lonchophylla peracchii Dias, Esbérard & Moratelli, 2013	Ca	N	NC	0	0	0	1	2	0	0	0	16	19
Subfamily Carolliinae													
Carollia brevicauda (Schinz, 1821)	A, Ca, C, P	F	LC	0	0	0	11	0	0	0	0	2	13
Carollia perspicillata (Linnaeus, 1758)	A, Ca, C, P and Pa	F	LC	80	6	3	88	23	2	4	1	79	287
Subfamily Glyphonycterinae													
Glyphonycteris daviesi (Hill, 1964)	A	I	LC	0	0	0	1	0	0	0	0	0	1
Glyphonycteris sylvestris Thomas, 1896	A	I	LC	2	0	0	2	0	0	0	0	0	4
Trinycteris nicefori (Sanborn, 1949)	A	I	LC	0	0	0	2	0	0	1	0	0	3
Subfamily Rhinophyllinae													

Rhinophylla pumilio Peters, 1865	A; C and Ca	F	LC	0	0	0	49	2	0	2	0	0	53
Subfamily Stenodermatinae													
Dermanura cinerea Gervais, 1856	A, C and Ca	F	LC	0	0	0	24	3	0	3	1	13	45
Artibeus fimbriatus Gray, 1838	A, Ca, C, P and Pa	F	LC	5	2	1	34	5	1	0	0	30	78
Dermanura gnoma (Handley, 1987)	A, C and Ca	F	LC	0	0	0	5	0	0	0	0	0	5
Artibeus lituratus (Olfers, 1818)	A, Ca, C, P and Pa	F	LC	46	4	4	55	16	2	3	1	61	192
Artibeus obscurus (Schinz, 1821)	A, Ca, C, P and Pa	F	LC	8	1	1	39	5	1	3	1	41	100
Artibeus planirostris (Spix, 1823)	A, Ca, C, P and Pa	F	LC	31	0	2	9	4	0	3	1	32	82
Chiroderma doriae Thomas, 1891	C and P	F	LC	24	0	0	1	1	0	2	1	30	59
Chiroderma villosum Peters, 1860	A, C and P	F	LC	9	0	2	7	2	0	1	0	15	36
Platyrrhinus incarum (Thomas, 1912)	A	F	LC	0	0	0	1	0	0	1	0	0	2
Platyrrhinus lineatus (É. Geoffroy, 1810)	A, Ca, C, P and Pa	F	LC	67	1	3	28	15	0	4	1	40	159
Platyrrhinus recifinus (Thomas, 1901)	C and Ca	F	LC	5	1	1	13	4	2	0	0	28	54
Pygoderma bilabiatum (Wagner, 1843)	C, Ca and P	F	LC	23	6	0	6	7	0	1	0	28	71

Sturnira lilium (É. Geoffroy, 1810)	A, Ca, C, P and Pa	F	LC	50	11	2	27	19	3	3	1	55	171
Sturnira tildae de la Torre, 1959	A, Ca, C and P	F	LC	9	3	0	3	0	1	0	0	14	30
Uroderma bilobatum Peters, 1866	A, Ca, C, P and Pa	F	LC	0	0	0	4	1	0	0	0	0	5
Uroderma magnirostrum Davis, 1968	A, Ca, C, P and Pa	F	LC	0	0	1	3	1	0	0	0	1	6
Vampyressa pusilla (Wagner, 1843)	C	F	DD	17	0	0	4	7	0	1	0	33	62
Vampyrodes caraccioli (Thomas, 1889)	A	F	LC	0	0	0	1	0	0	0	0	3	4
Family Noctilionidae													
Noctilio albiventris Desmarest, 1818	A, Ca, C and P	I	LC	16	0	0	0	0	0	0	0	1	17
Noctilio leporinus (Linnaeus, 1758)	A, Ca, C and P	P	LC	7	0	1	6	5	0	0	1	13	33
Family Furipteridae													
Furipterus horrens (Cuvier, 1828)	A, C and Ca	I	LC	3	0	0	1	0	0	0	0	4	8
Family Thyropteridae													
Thyroptera tricolor Spix, 1823	A	I	LC	0	0	0	0	1	0	0	0	3	4
Family Natalidae													

Natalus macrourus (Gervais, 1856)	A, C and Ca	I	NT	1	0	0	0	1	0	0	0	0	2
Total of Species in ecoregions				**37**	**17**	**19**	**53**	**38**	**15**	**32**	**18**	**45**	**59**

APPENDIX S2

Rasters of environmental variables and graphic representations of splines that were generated based on environmental variables included in the GDM of bat species composition (βsim) in the Atlantic Forest. The x axis is the predicted ecological distance and y axis is the observed distance. The height of spline indicates the magnitude of biological change along that gradient and represents the relative importance of each predictor contributing to the turnover component. The shape of the spline indicates where, along each gradient, the changes are most pronounced.

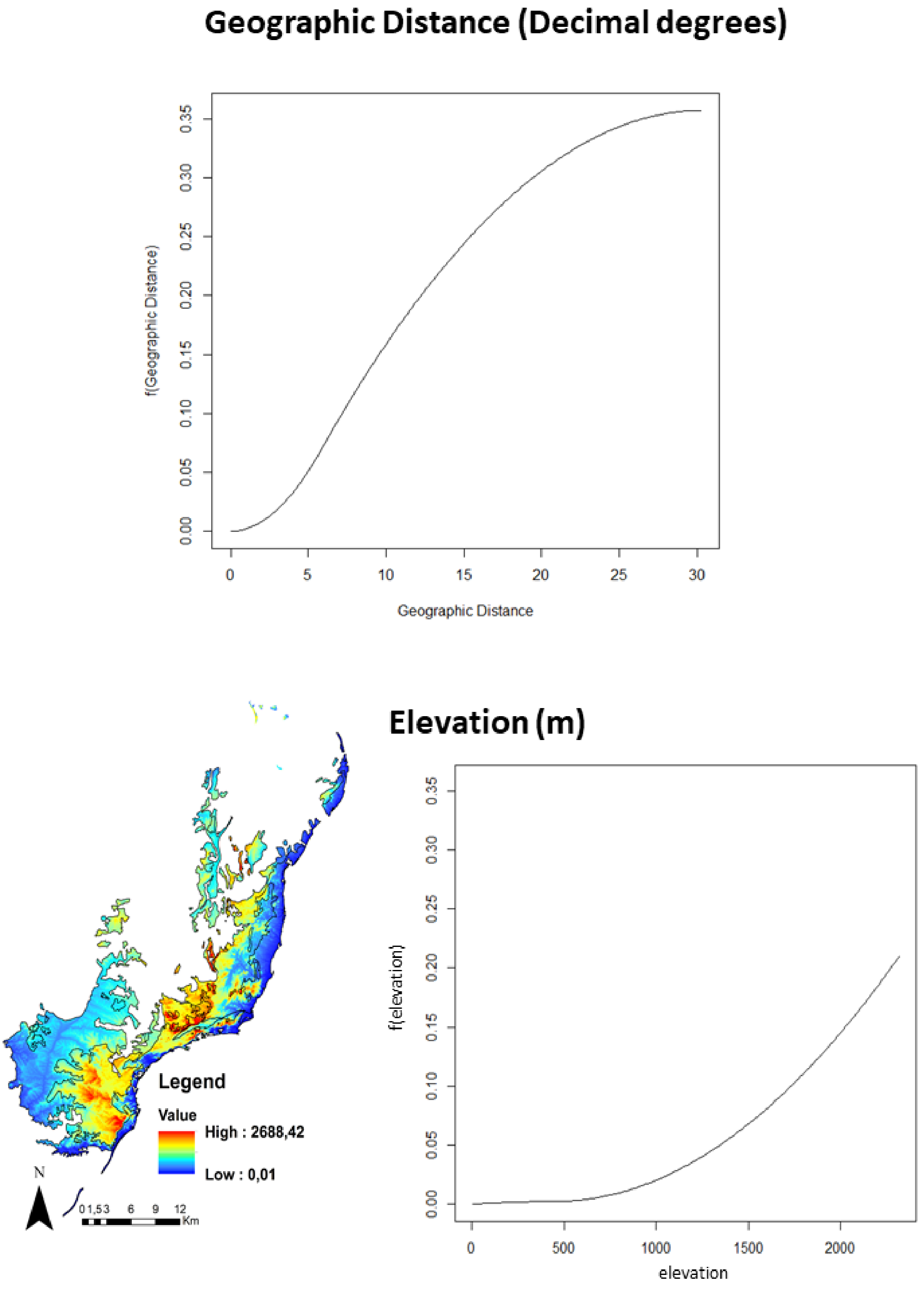
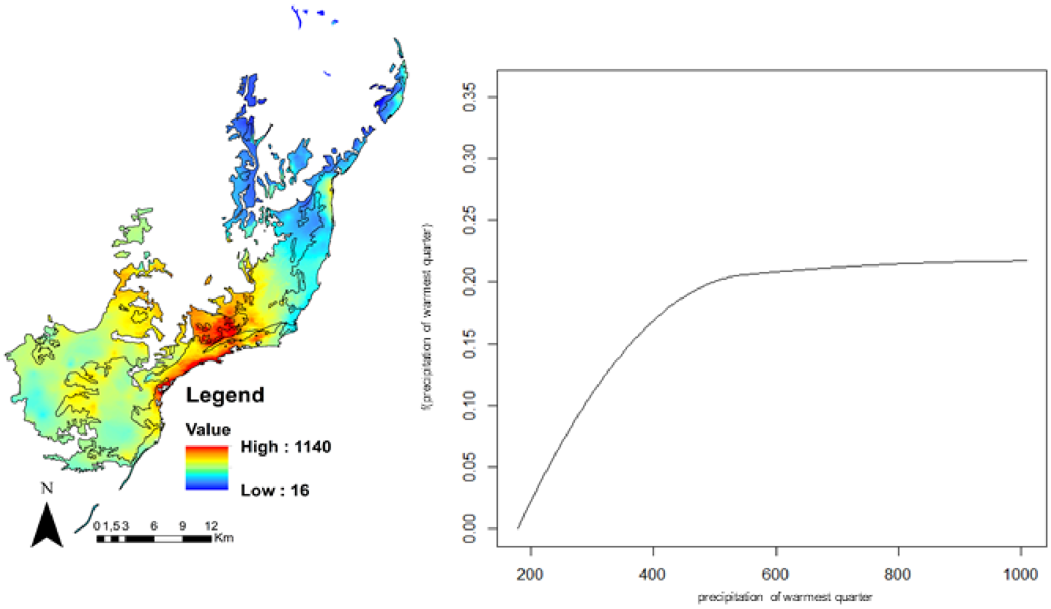


Figure S1.2 Rasters of geographical distance and altitude, and graphic representations of splines that were generated based on environmental variables included in the GDM of bat species composition (βsim) in the Atlantic Forest. The x axis is the predicted ecological distance and y axis is the observed distance. The height of spline indicates the magnitude of biological change along that gradient and represents the relative importance of each predictor contributing to the turnover component. The shape of the spline indicates where, along each gradient, the changes are most pronounced.

Precipitation of warmest quarter (mm)



Precipitation of coldest quarter (mm)

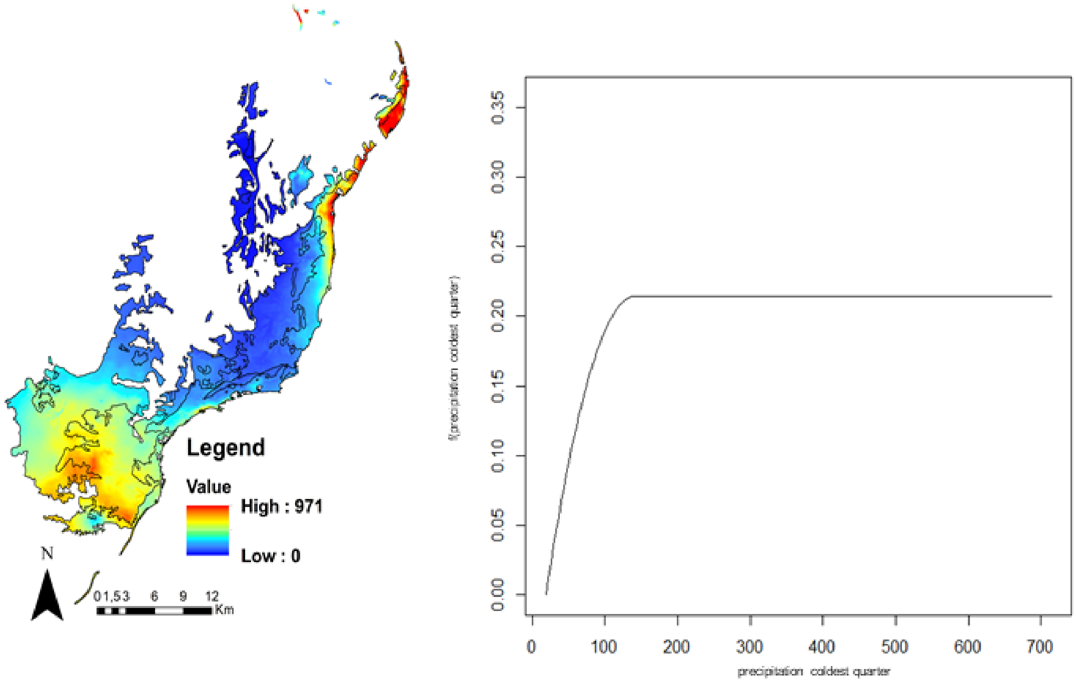
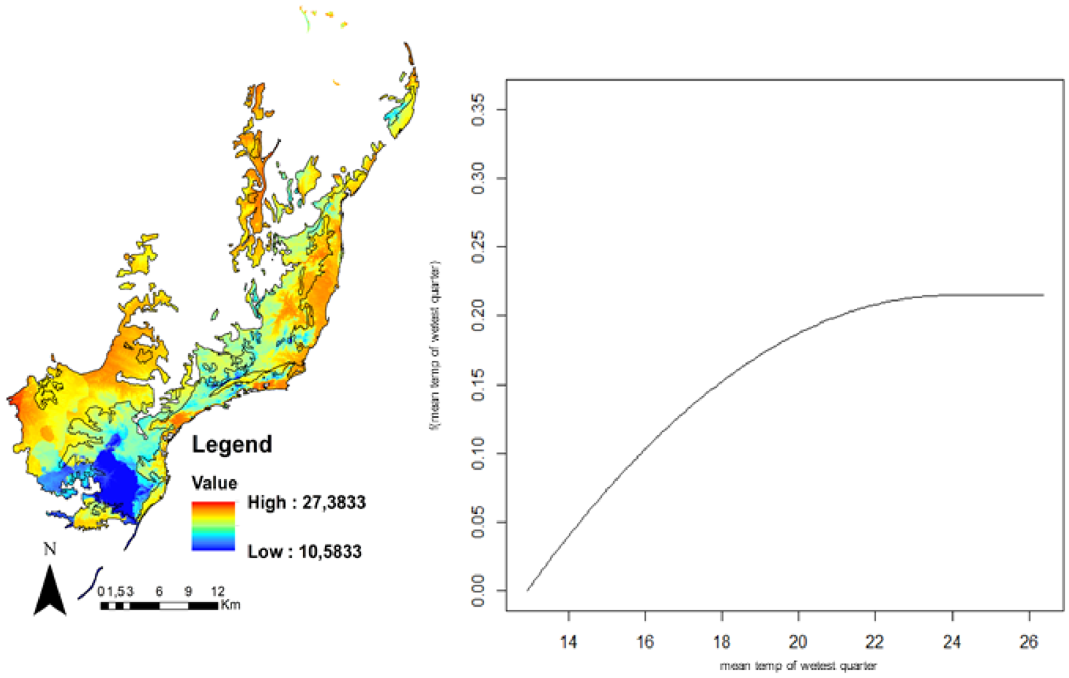


Figure S2.2 Rasters of precipitation of warmest quarter and precipitation of coldest quarter, and graphic representations of splines that were generated based on environmental variables included in the GDM of bat species composition (βsim) in the Atlantic Forest. The x axis is the predicted ecological distance and y axis is the observed distance. The height of spline indicates the magnitude of biological change along that gradient and represents the relative importance of each predictor contributing to the turnover component. The shape of the spline indicates where, along each gradient, the changes are most pronounced.

Mean temperature of wettest quarter (°C)



Minimum temperature of coldest month (°C)

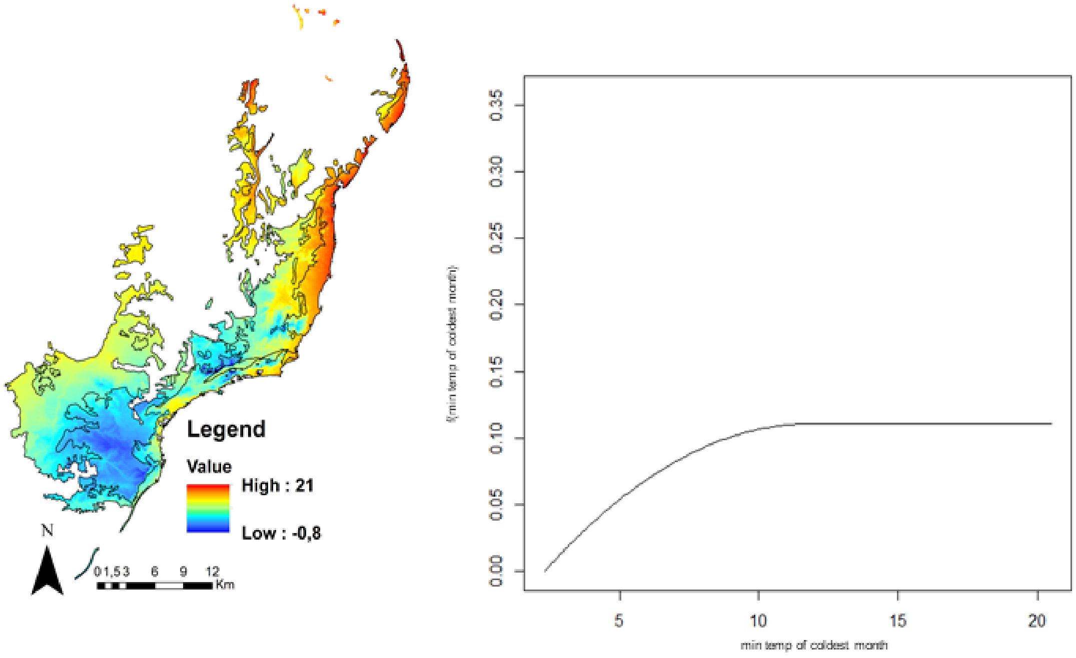
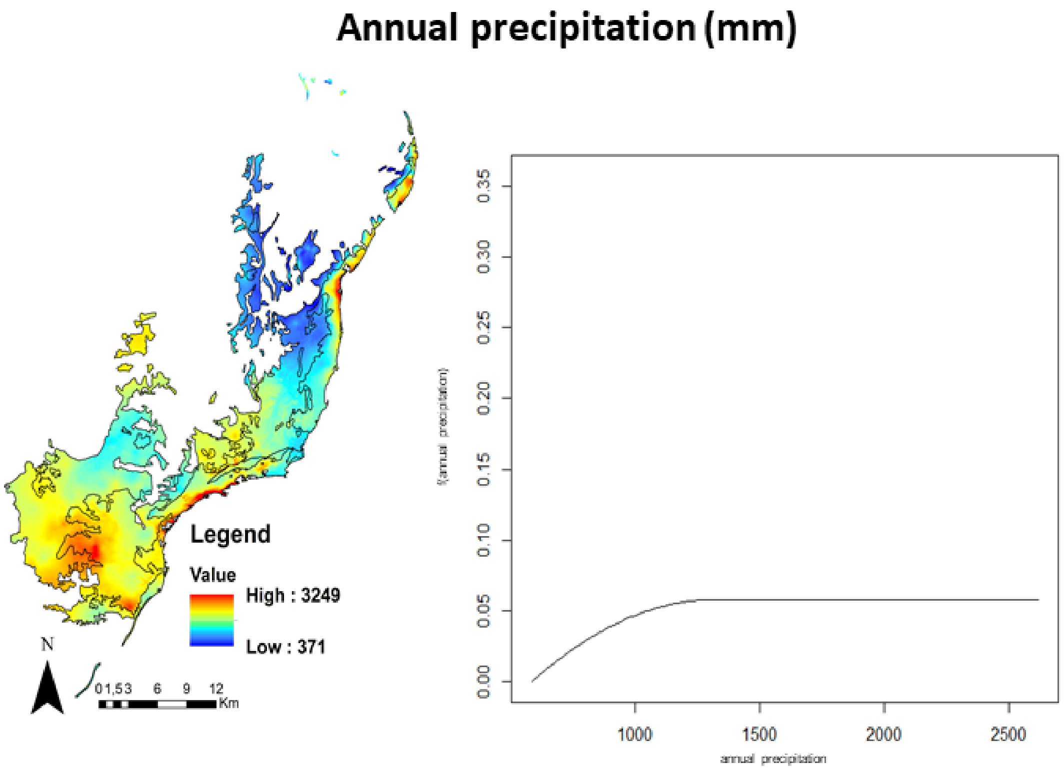


Figure S3.2 Rasters of mean temperature of wettest quarter and minimum temperature of coldest month, and graphic representations of splines that were generated based on environmental variables included in the GDM of bat species composition (βsim) in the Atlantic Forest. The x axis is the predicted ecological distance and y axis is the observed distance. The height of spline indicates the magnitude of biological change along that gradient and represents the relative importance of each predictor contributing to the turnover component. The shape of the spline indicates where, along each gradient, the changes are most pronounced.



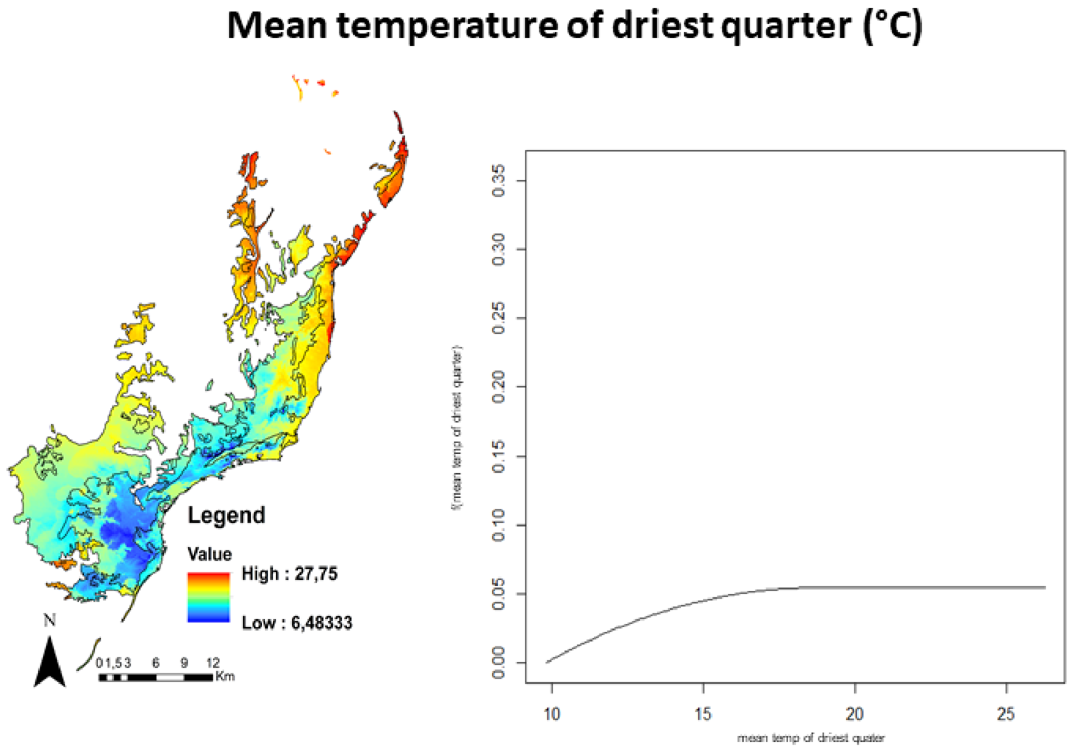
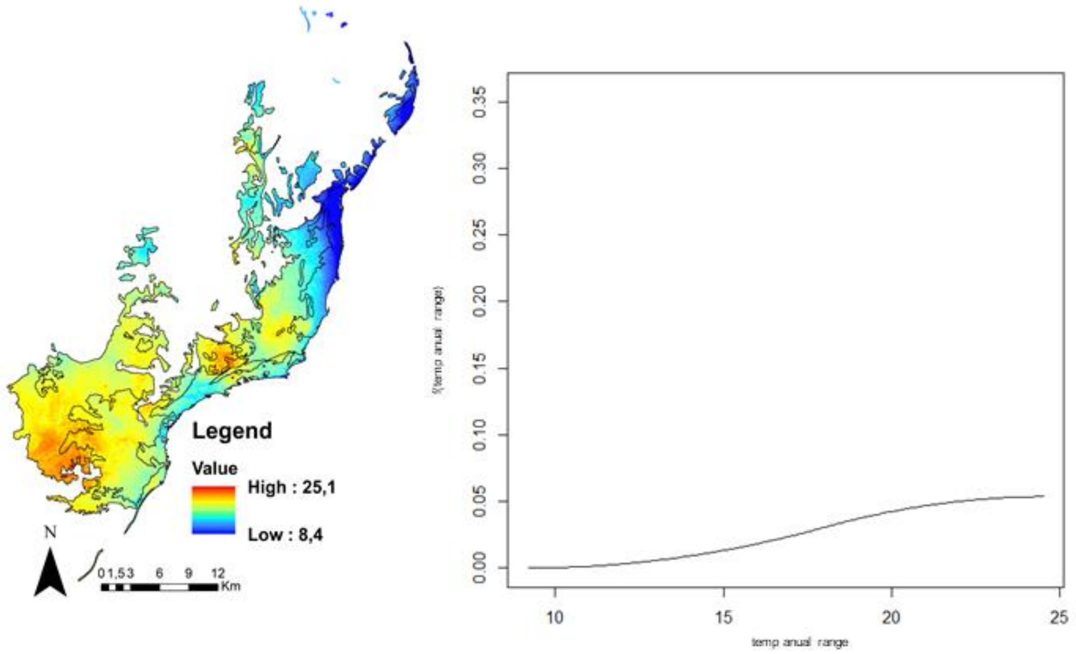


Figure S4.2 Rasters of annual precipitation and mean temperature of driest quarter, and graphic representations of splines that were generated based on environmental variables included in the GDM of bat species composition (βsim) in the Atlantic Forest. The x axis is the predicted ecological distance and y axis is the observed distance. The height of spline indicates the magnitude of biological change along that gradient and represents the relative importance of each predictor contributing to the turnover component. The shape of the spline indicates where, along each gradient, the changes are most pronounced.

Temperature anual range (°C)



Mean diurnal range (°C)

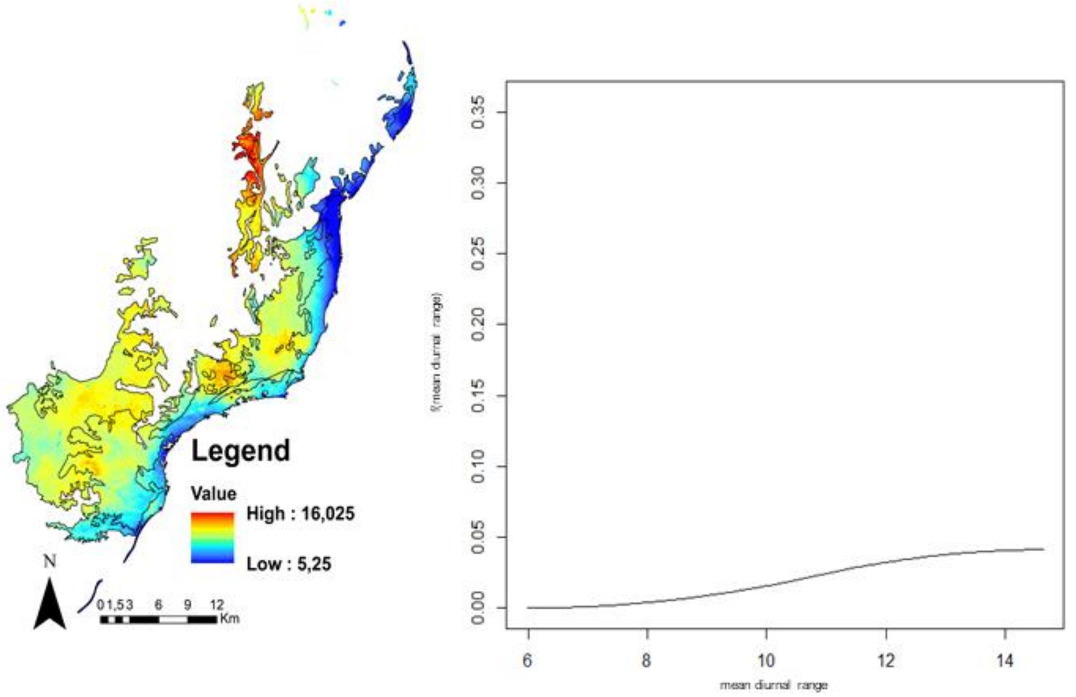


Figure S5.2 Rasters of temperature annual range and mean diurnal range, and graphic representations of splines that were generated based on environmental variables included in the GDM of bat species composition (βsim) in the Atlantic Forest. The x axis is the predicted ecological distance and y axis is the observed distance. The height of spline indicates the magnitude of biological change along that gradient and represents the relative importance of each predictor contributing to the turnover component. The shape of the spline indicates where, along each gradient, the changes are most pronounced.

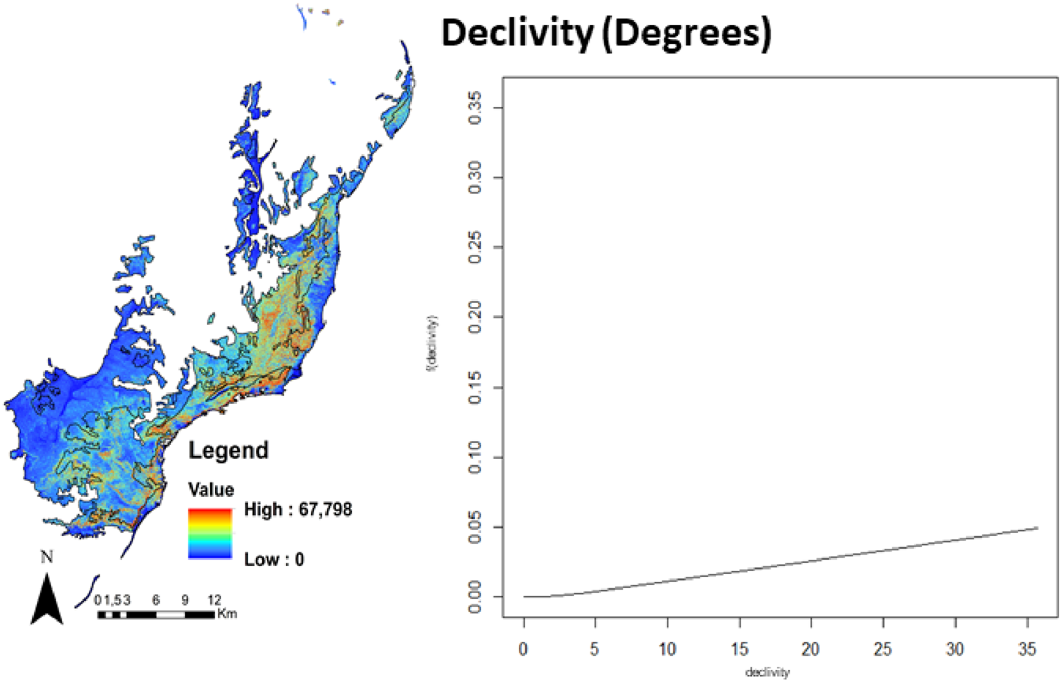


Figure S6.2 Raster of declivity graphic representations of splines that were generated based on environmental variables included in the GDM of bat species composition (βsim) in the Atlantic Forest. The x axis is the predicted ecological distance and y axis is the observed distance. The height of spline indicates the magnitude of biological change along that gradient and represents the relative importance of each predictor contributing to the turnover component. The shape of the spline indicates where, along each gradient, the changes are most pronounced.

APPENDIX S3

Pairwise indexes matrix and clusters of turnover (βsim), nestedness (βsne**)** and total beta diversity (βsØr) of bats species between Atlantic Forest ecoregions and regions. These matrix and clusters are results from Beta diversity analysis (Betapart/R-project) and the index was calculated from a matrix of presence and absence of species in each ecoregion.

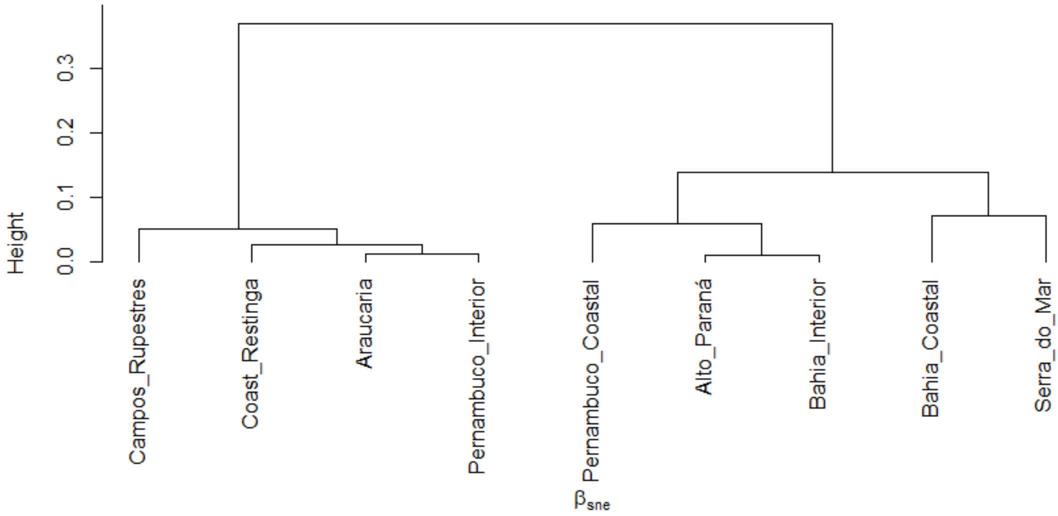


Figure S7.3 Cluster of nestedness (βsne) of bats species between Atlantic Forest ecoregions. Values range from zero (no nestedness between groups) to one (All species are shared between regions). The height varied from 0.01 to 0.55. This cluster is result from Beta diversity analysis (Betapart/R-project) and the index was calculated from a matrix of presence and absence of species in each ecoregion.

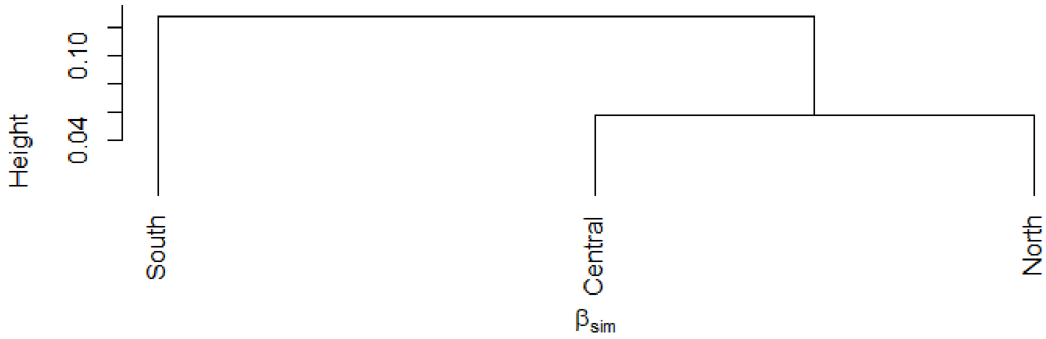


Figure S8.3 Cluster of turnover (βsim) of bats species between Atlantic Forest regions (South, Central and North). South: include the occurrence sites to species in Serra do Mar, Alto Parana, Araucarias and Campos Rupestres ecoregions; Central: include the occurrence sites to species in Bahia Coastal, Bahia Interior and Coast Restinga ecoregions; and the North include the occurrence sites to species in Pernambuco Coastal and Pernambuco Interior ecoregions. Values range from zero (species composition is the same between both groups) to one (no species are shared between regions). The height varied from 0.04 to 0.10. This cluster is result from Beta diversity analysis (Betapart/R-project) and the index was calculated from a matrix of presence and absence of species in each ecoregion.

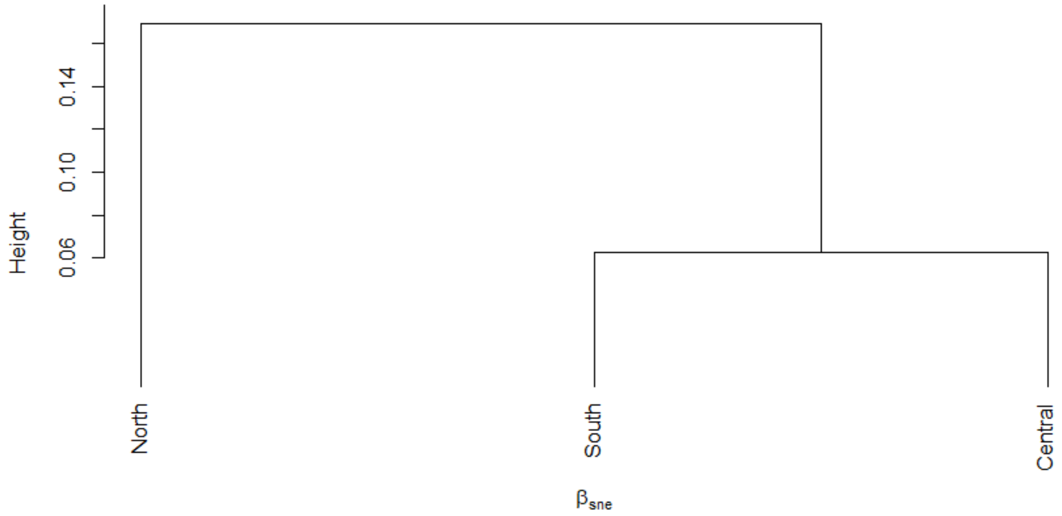


Figure S9.3 Cluster of nestedness (βsne) of bats species between Atlantic Forest regions. South: include the occurrence sites to species in Serra do Mar, Alto Parana, Araucarias and Campos Rupestres ecoregions; Central: include the occurrence sites to species in Bahia Coastal, Bahia Interior and Coast Restinga ecoregions; and the North include the occurrence sites to species in Pernambuco Coastal and Pernambuco Interior ecoregions. Values range from zero (no nestedness between groups) to one (All species are shared between regions). The height varied from 0.06 to 0.20. This cluster is result from Beta diversity analysis (Betapart/R-project) and the index was calculated from a matrix of presence and absence of species in each ecoregion.

Table S2.3 Pairwise indexes matrix of turnover (βsim), nestedness (βsne**)** and total beta diversity (βsØr) of bats species between ecoregions in the south of the Atlantic Forest. This matrix is result from Beta diversity analysis (Betapart/R-project) and the index was calculated from a matrix of presence and absence of species in each ecoregion. .

	South		
	Alto Paraná	**Araucaria**	**Campos Rupestres**
Tunover (βsim) - 0.07042254			

Araucaria	0.00000000		
Campos Rupestres	0.00000000	0.13333333	
Serra do Mar	0.08108108	0.00000000	0.00000000
Nestedness (βsne) - 0.4057679			
Araucaria	0.37037037		
Campos Rupestres	0.42307692	0.05416667	
Serra do Mar	0.08965063	0.45161290	0.50000000
Beta diversity (βsØr) - 0.4761905			
Araucaria	0.3703704		
Campos Rupestres	0.4230769	0.1875000	
Serra do Mar	0.1707317	0.4516129	0.5000000

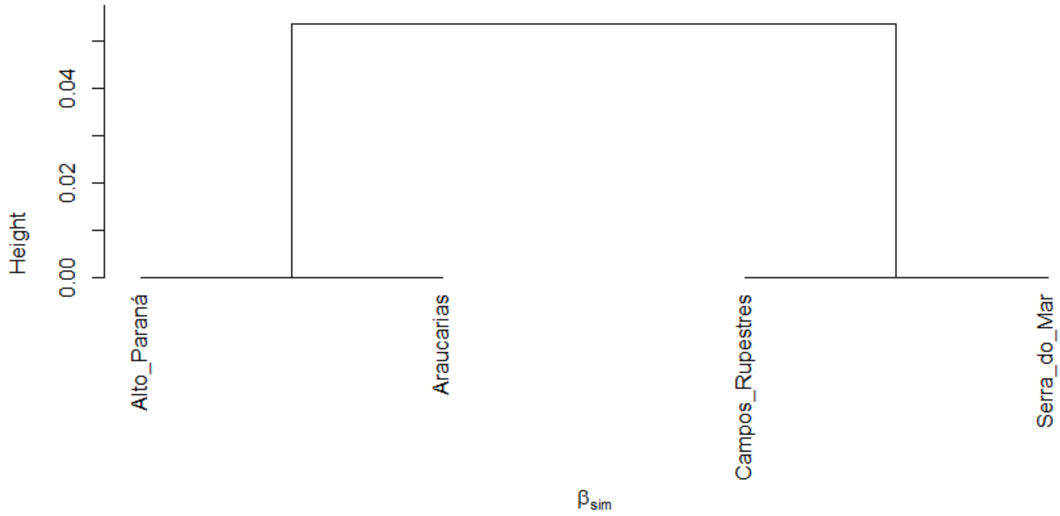


Figure S10.3 Cluster of turnover (βsim) of bats species between the ecoregions located in the south of the Atlantic Forest. Values range from zero (when species composition is the same between both groups) to one (no species are shared between regions). The height varied from 0.00 to 0.05. This cluster is result from Beta diversity analysis (Betapart/R-project) and the index was calculated from a matrix of presence and absence of species in each ecoregion. .

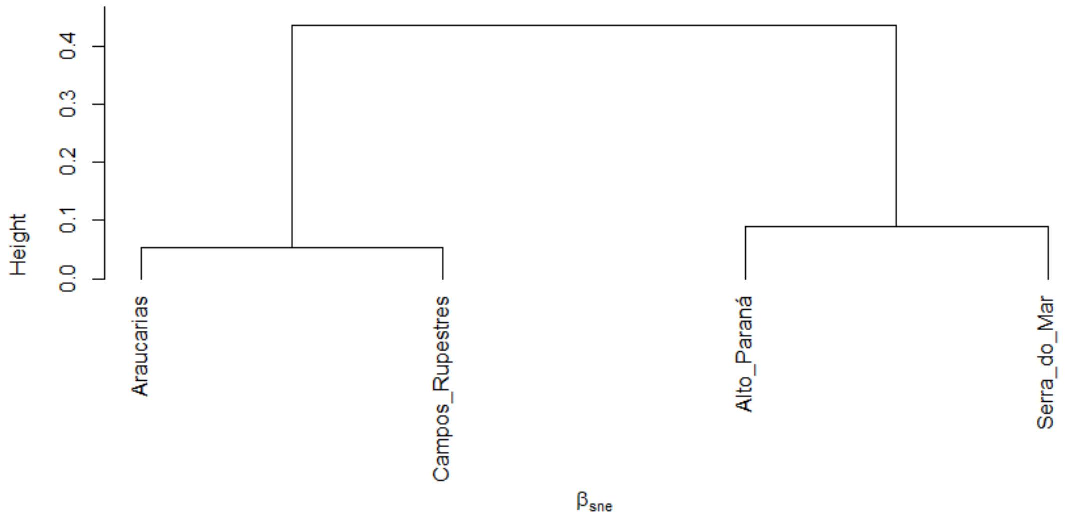


Figure S11.3 Cluster of nestedness (βsne) of bats species between the ecoregions located in the south of the Atlantic Forest. Values range from zero (no nestedness between groups) to one (All species are shared between regions). The height varied from 0.05 to 0.45. This cluster is result from Beta diversity analysis (Betapart/R-project) and the index was calculated from a matrix of presence and absence of species in each ecoregion.

Table S3.3 Pairwise indexes matrix of turnover (βsim), nestedness (βsne**)** and total beta diversity (βsØr) of bats species between ecoregions in the centre of the Atlantic Forest. This matrix is result from Beta diversity analysis (Betapart/R-project) and the index was calculated from a matrix of presence and absence of species in each ecoregion.

Centre		
	Coast Restinga	**Bahia Coastal**
Tunover (βsim) - 0.05172414		
Bahia Coastal	0.00000000	
Bahia Interior	0.05263158	0.05263158
Nestedness (βsne) - 0.3504498		
Bahia Coastal	0.4722222	
Bahia Interior	0.3157895	0.1561596
Beta diversity (βsØr) - 0.4021739		
Bahia Coastal	0.4722222	
Bahia Interior	0.3684211	0.2087912

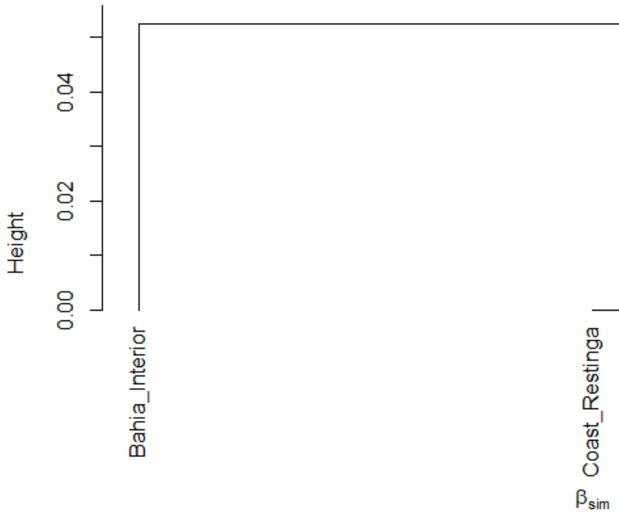


Figure S12.3 Cluster of turnover (βsim) of bats species between the ecoregions located in the center of the Atlantic Forest. Values range from zero (when species composition is the same between both groups) to one (no species are shared between regions). The height varied from 0.00 to 0.05. This cluster is result from Beta diversity analysis (Betapart/R-project) and the index was calculated from a matrix of presence and absence of species in each ecoregion.

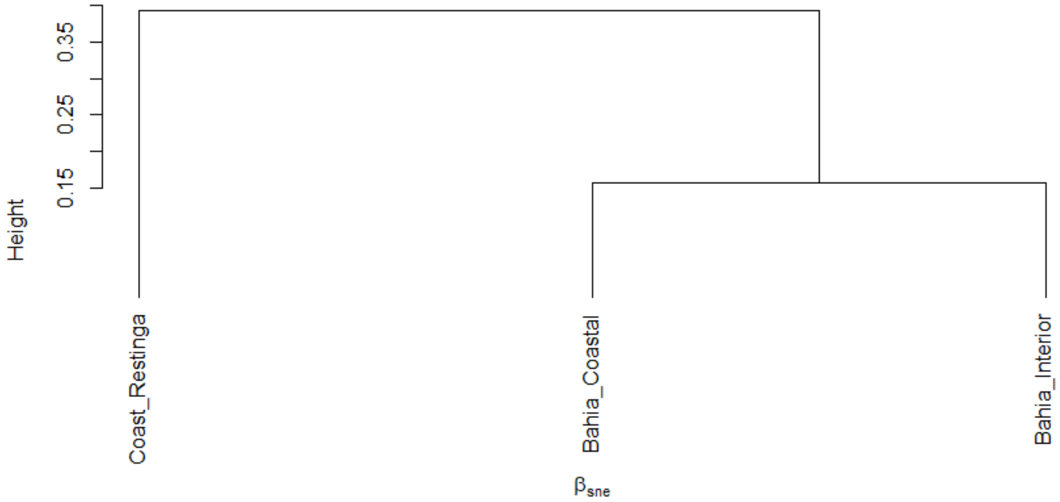


Figure S13.3 Cluster of nestedness (βsne) of bats species between the ecoregions located in the center of the Atlantic Forest. Values range from zero (no nestedness between groups) to one (All species are shared between regions). The height varied from 0.15 to 0.47. This cluster is result from Beta diversity analysis (Betapart/R-project) and the index was calculated from a matrix of presence and absence of species in each ecoregion.

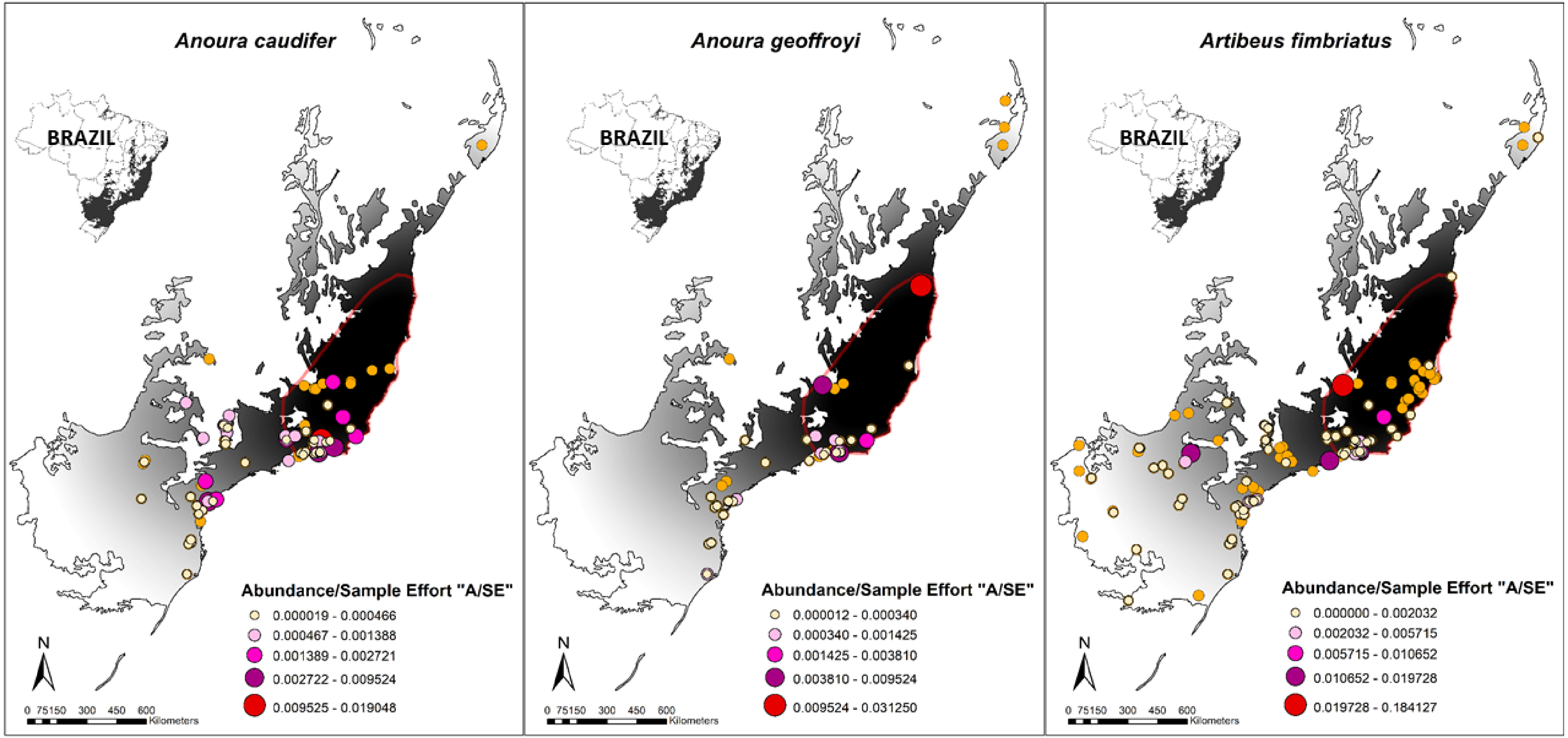
Table S4.3 Pairwise indexes matrix of turnover (βsim), nestedness (βsne**)** and total beta diversity (βsØr) of bats species between ecoregions in the north of the Atlantic Forest. This matrix is result from Beta diversity analysis (Betapart/R-project) and the index was calculated from a matrix of presence and absence of species in each ecoregion.

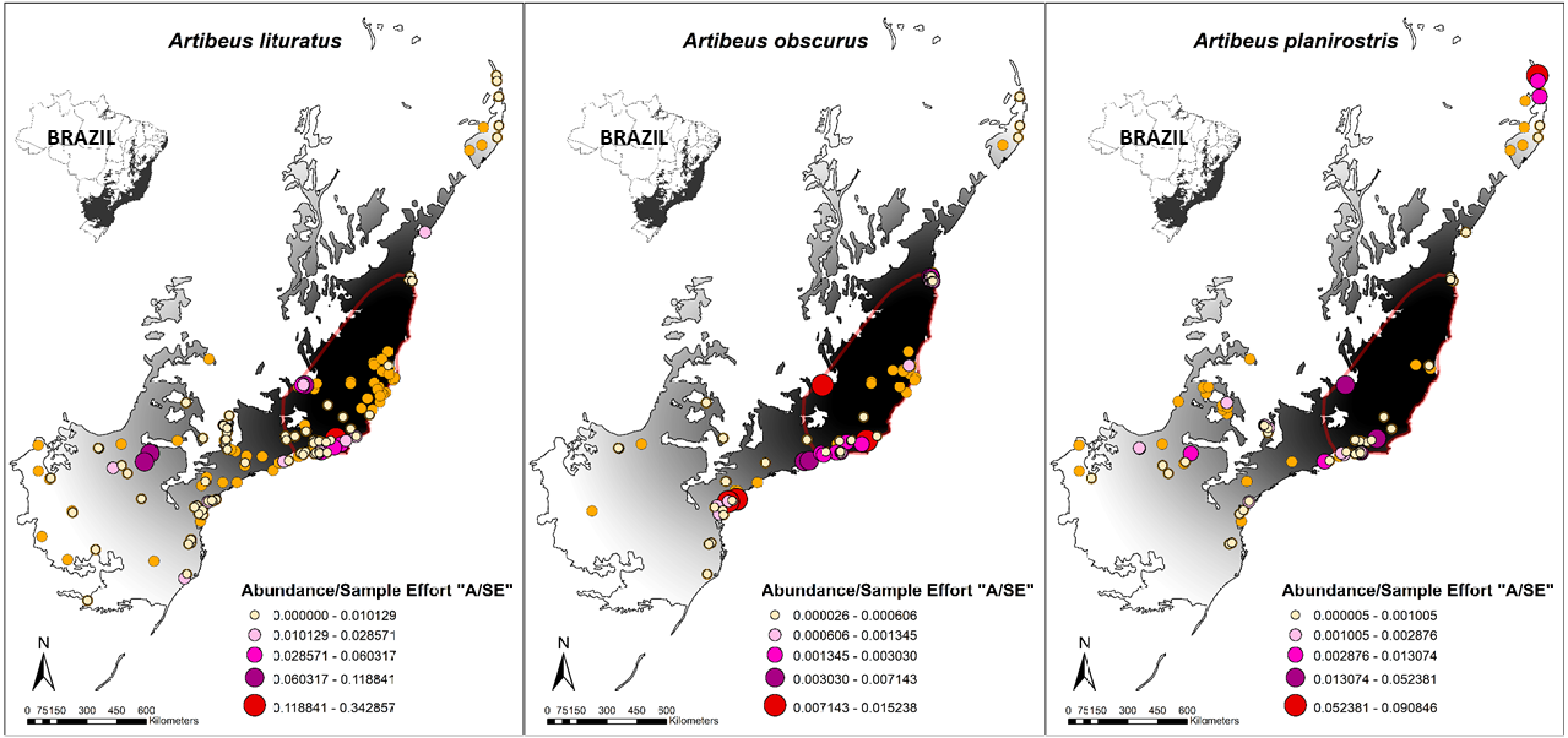
North	
	Pernambuco Coastal
Tunover (βsim) - 0.1666667	
Pernambuco Interior	0.1666667
Nestedness (βsne) - 0.2333333	
Pernambuco Interior	0.2333333
Beta diversity (βsØr) - 0.4	
Pernambuco Interior	0.4

APÊNDICE C

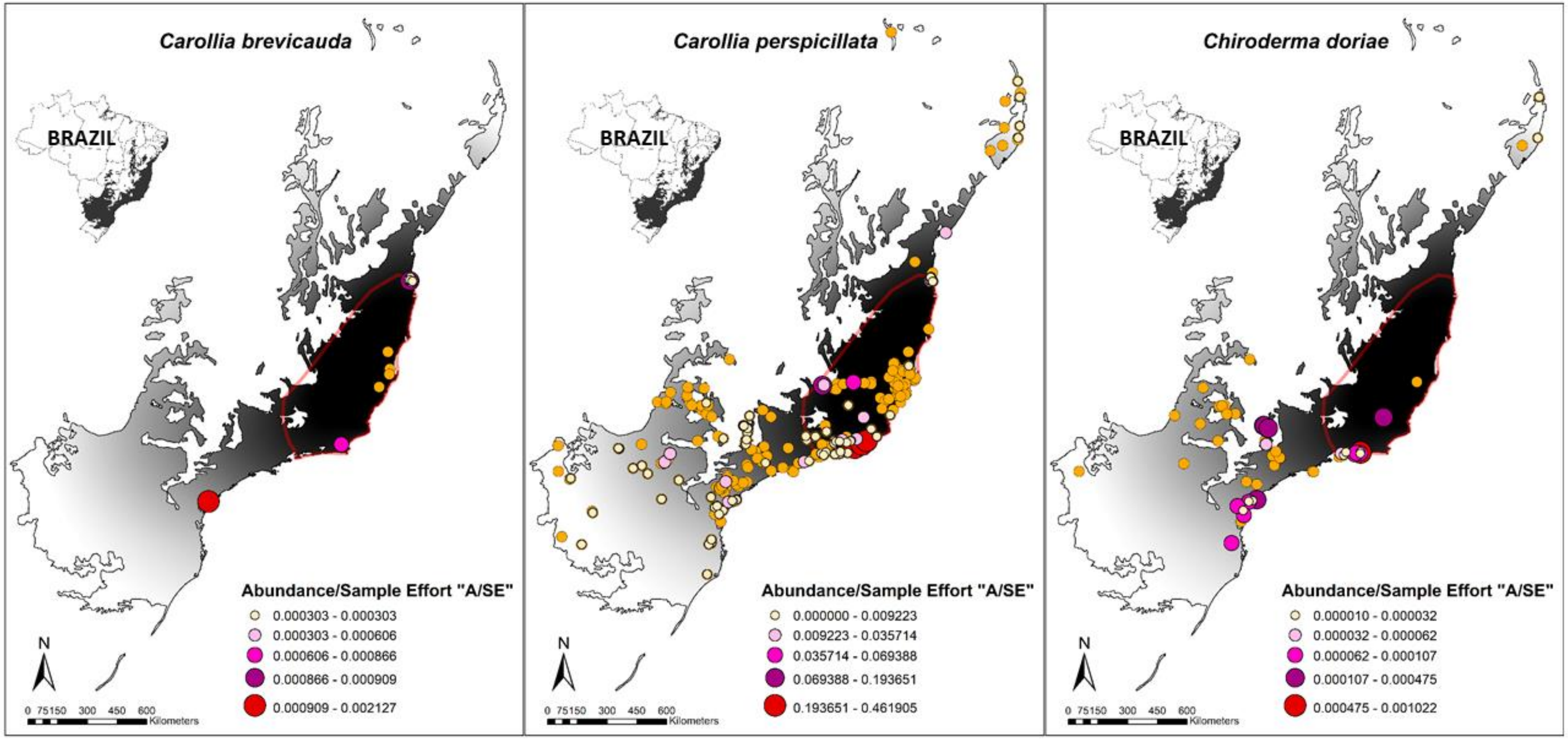
Material suplementar do Capítulo 3. O material encontra-se nas normas do periódico “Biological Conservation”.

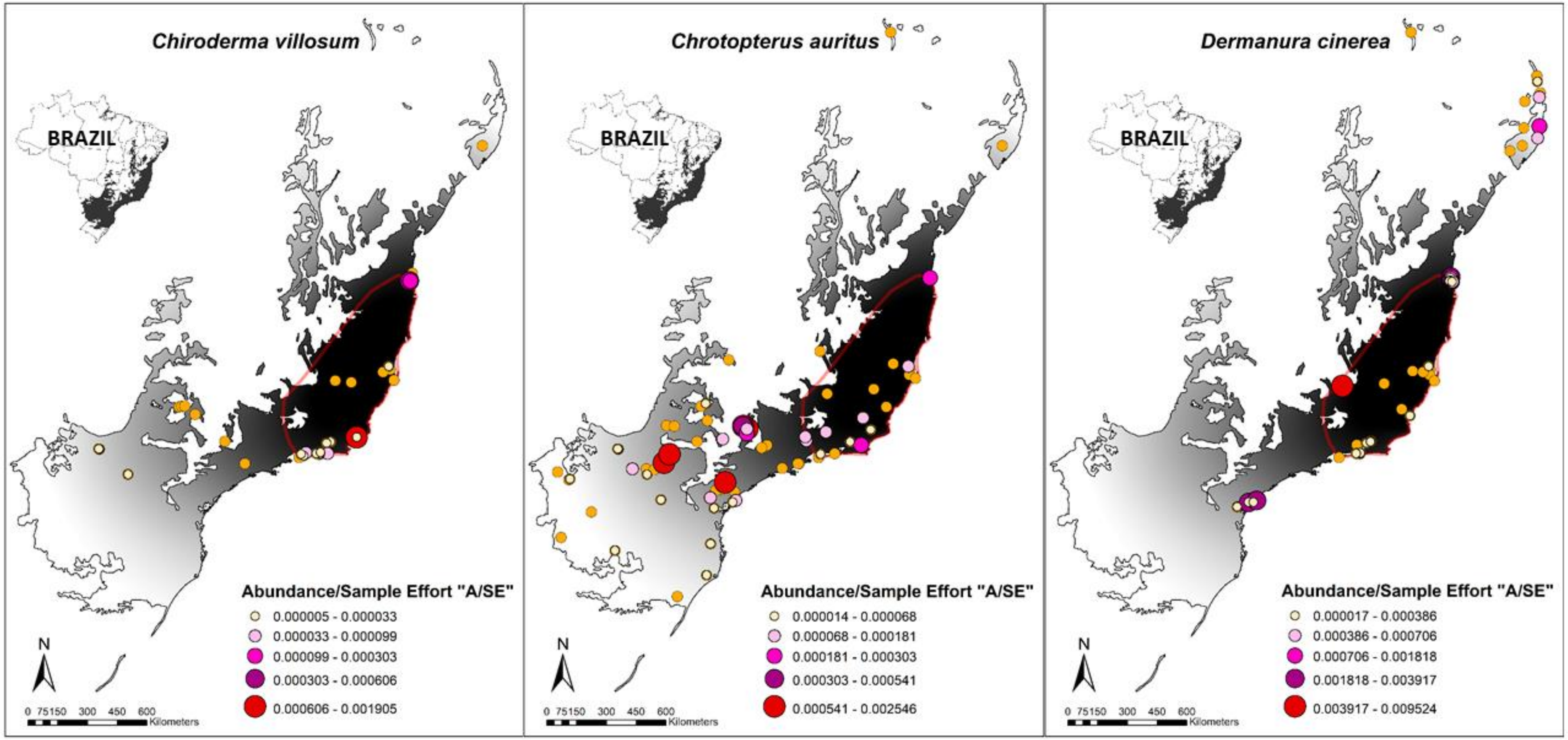
Distribution maps of the 59 bat species in the Atlantic Forest included in our study. The orange dots represent georeferenced occurrence sites without sampling effort information, therefore without the Abundance / Effort Sample (“A / SE”) index. The red boundary represents the limits of the congruence area for 58 of the 59 species. The 58 species that had the “A / SE” index calculated have points of colors and sizes that vary according to the index, and are in the caption of each map.

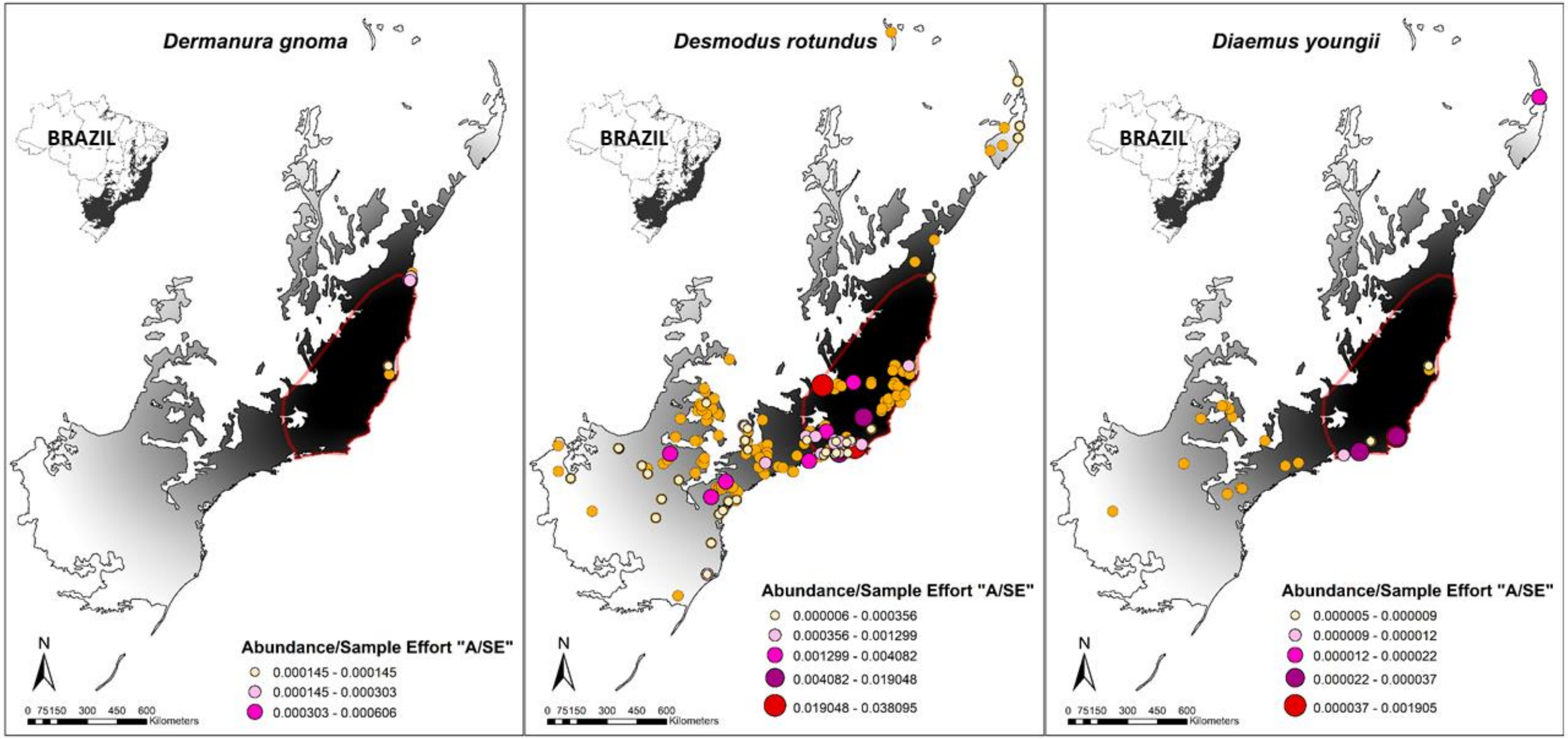

Anoura caudifer
BRAZIL
Abundance/Sample Effort "A/SE"
0.000019 - 0.000466
0.000467 - 0.001388
0.001389 - 0.002721
0.002722 - 0.009524
0.009525 - 0.019048
N
0 75150 300 450 600
Kilometers
Anoura geoffroyi
BRAZIL
Abundance/Sample Effort "A/SE"
0.000012 - 0.000340
0.000340 - 0.001425
0.001425 - 0.003810
0.003810 - 0.009524
0.009524 - 0.031250
N
0 75150 300 450 600
Kilometers
Artibeus fimbriatus
BRAZIL
Abundance/Sample Effort "A/SE"
0.000000 - 0.002032
0.002032 - 0.005715
0.005715 - 0.010652
0.010652 - 0.019728
0.019728 - 0.184127
N
0 75150 300 450 600
Kilometers

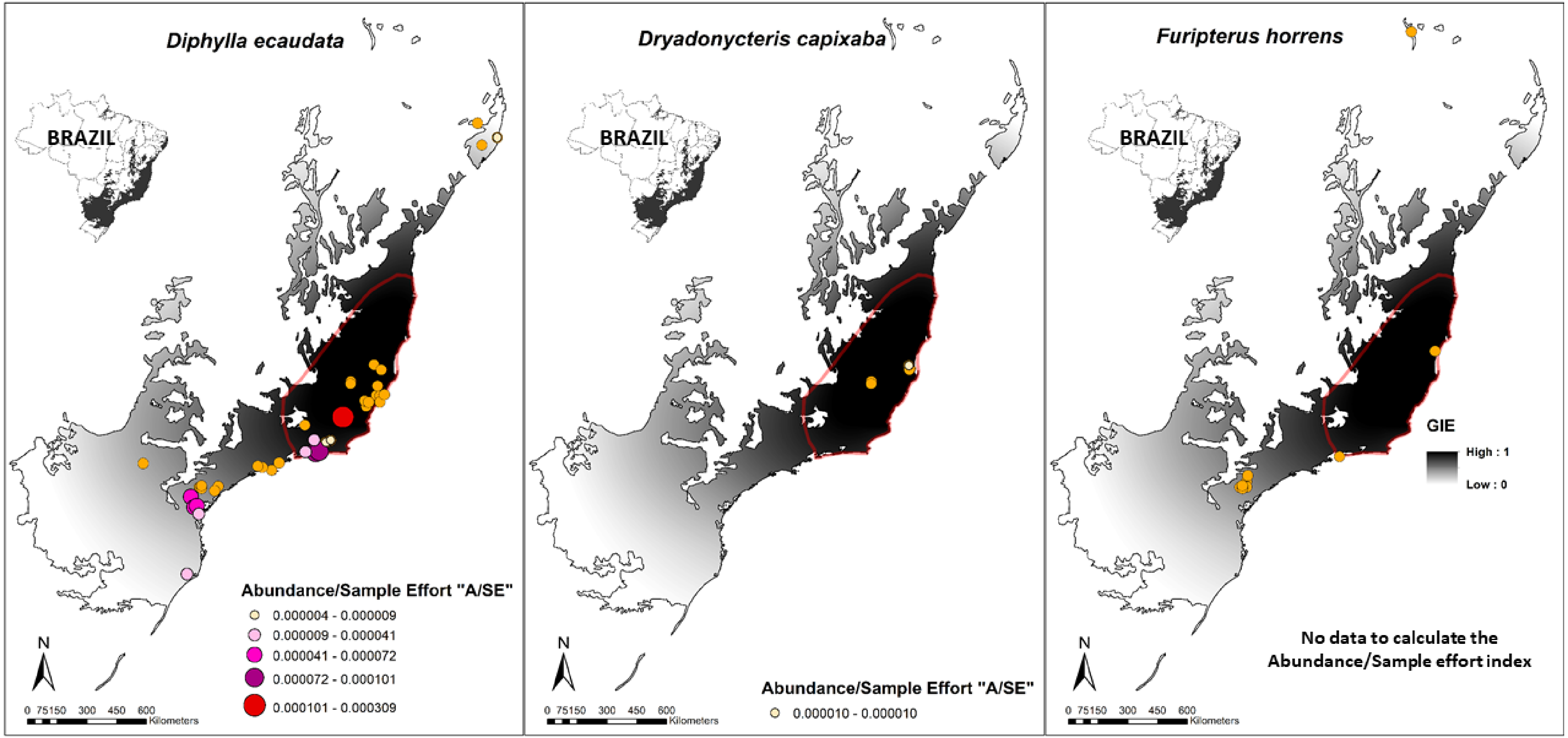

Artibeus lituratus
BRAZIL
Abundance/Sample Effort "A/SE"
0.000000 - 0.010129
0.010129 - 0.028571
0.028571 - 0.060317
0.060317 - 0.118841
0.118841 - 0.342857
N
0 75150 300 450 600
Kilometers
Artibeus obscurus
BRAZIL
Abundance/Sample Effort "A/SE"
0.000026 - 0.000606
0.000606 - 0.001345
0.001345 - 0.003030
0.003030 - 0.007143
0.007143 - 0.015238
N
0 75150 300 450 600
Kilometers
Artibeus planirostris
BRAZIL
Abundance/Sample Effort "A/SE"
0.000005 - 0.001005
0.001005 - 0.002876
0.002876 - 0.013074
0.013074 - 0.052381
0.052381 - 0.090846
N
0 75150 300 450 600
Kilometers

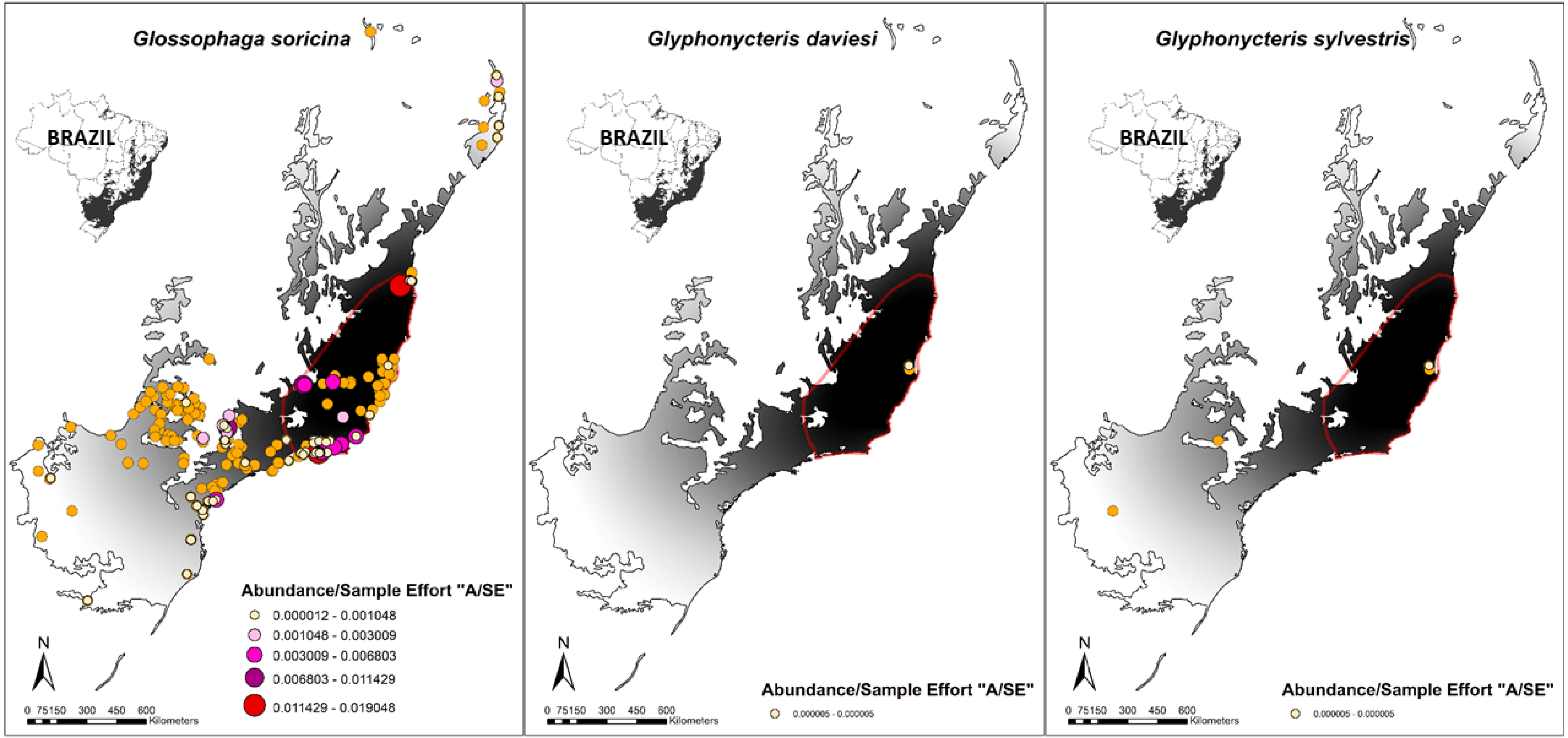
7


Carollia brevicauda
BRAZIL
Abundance/Sample Effort "A/SE"
0.000303 - 0.000303
0.000303 - 0.000606
0.000606 - 0.000866
0.000866 - 0.000909
0.000909 - 0.002127
N
0 75150 300 450 600
Kilometers
Carollia perspicillata
BRAZIL
Abundance/Sample Effort "A/SE"
0.000000 - 0.009223
0.009223 - 0.035714
0.035714 - 0.069388
0.069388 - 0.193651
0.193651 - 0.461905
N
0 75150 300 450 600
Kilometers
Chiroderma doriae
BRAZIL
Abundance/Sample Effort "A/SE"
0.000010 - 0.000032
0.000032 - 0.000062
0.000062 - 0.000107
0.000107 - 0.000475
0.000475 - 0.001022
N
0 75150 300 450 600
Kilometers

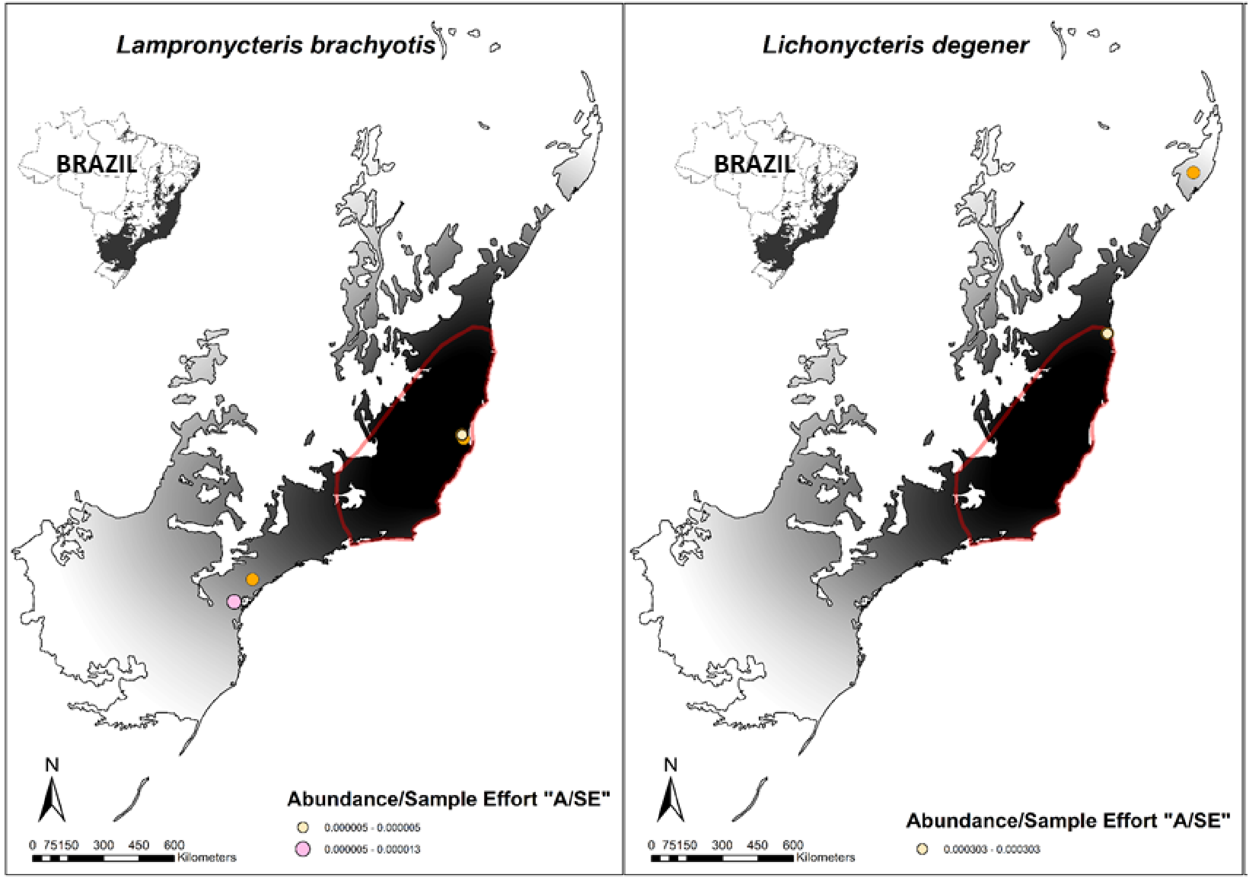

Chiroderma villosum
BRAZIL
Abundance/Sample Effort "A/SE"
0.000005 - 0.000033
0.000033 - 0.000099
0.000099 - 0.000303
0.000303 - 0.000606
0.000606 - 0.001905
N
0 75150 300 450 600 Kilometers
Chrotopterus auritus
BRAZIL
Abundance/Sample Effort "A/SE"
0.000014 - 0.000068
0.000068 - 0.000181
0.000181 - 0.000303
0.000303 - 0.000541
0.000541 - 0.002546
N
0 75150 300 450 600 Kilometers
Dermanura cinerea
BRAZIL
Abundance/Sample Effort "A/SE"
0.000017 - 0.000386
0.000386 - 0.000706
0.000706 - 0.001818
0.001818 - 0.003917
0.003917 - 0.009524
N
0 75150 300 450 600 Kilometers


Dermanura gnoma
BRAZIL
Abundance/Sample Effort "A/SE"
0.000145 - 0.000145
0.000145 - 0.000303
0.000303 - 0.000606
N
0 75150 300 450 600 Kilometers
Desmodus rotundus
BRAZIL
Abundance/Sample Effort "A/SE"
0.000006 - 0.000356
0.000356 - 0.001299
0.001299 - 0.004082
0.004082 - 0.019048
0.019048 - 0.038095
N
0 75150 300 450 600 Kilometers
Diaemus youngii
BRAZIL
Abundance/Sample Effort "A/SE"
0.000005 - 0.000009
0.000009 - 0.000012
0.000012 - 0.000022
0.000022 - 0.000037
0.000037 - 0.001905
N
0 75150 300 450 600 Kilometers

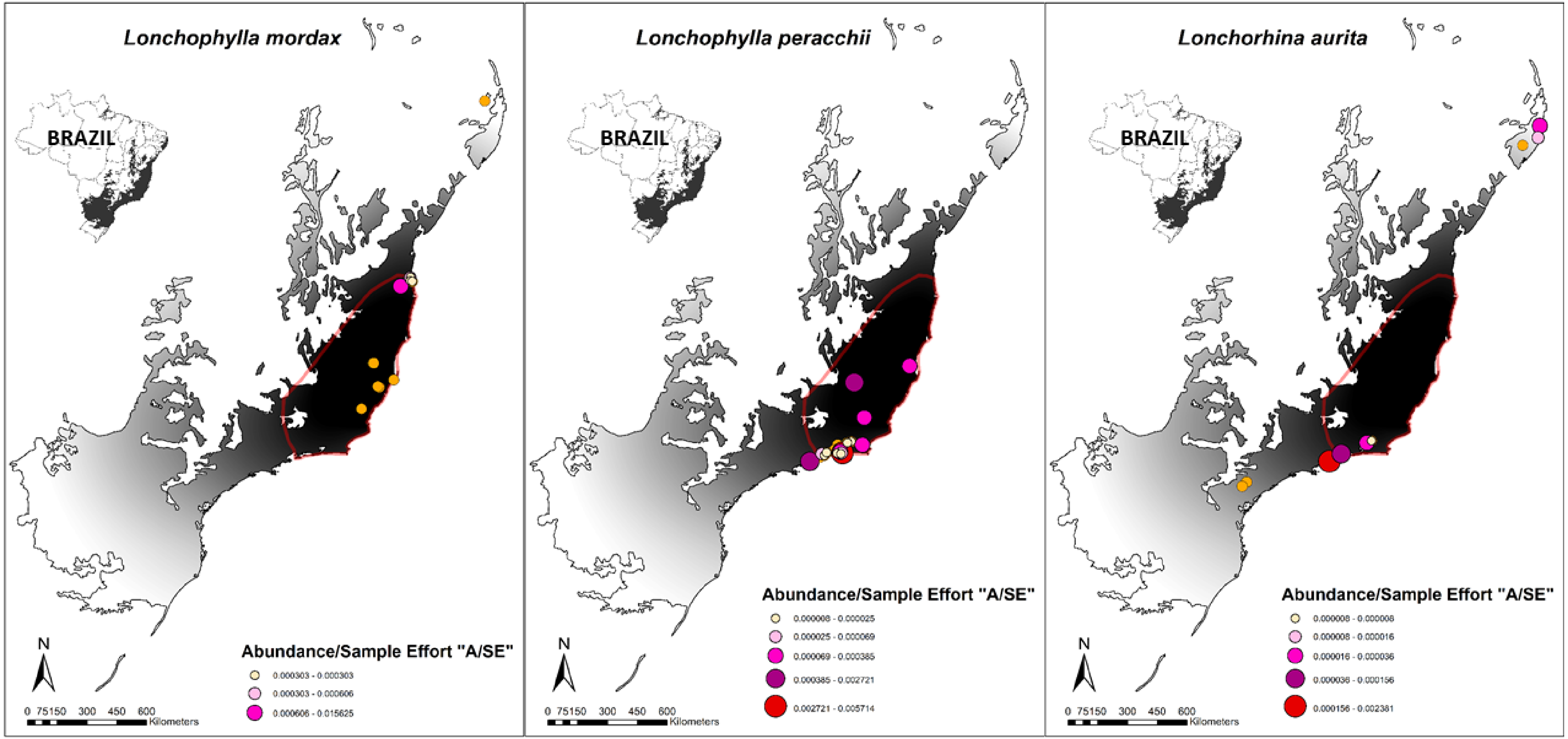

Diphylla ecaudata
BRAZIL
Abundance/Sample Effort "A/SE"
0.000004 - 0.000009
0.000009 - 0.000041
0.000041 - 0.000072
0.000072 - 0.000101
0.000101 - 0.000309
N
0 75150 300 450 600
Kilometers
Dryadonycteris capixaba
BRAZIL
Abundance/Sample Effort "A/SE"
0.000010 - 0.000010
N
0 75150 300 450 600
Kilometers
Furipterus horrens
BRAZIL
GIE
High : 1
Low : 0
No data to calculate the
Abundance/Sample effort index
N
0 75150 300 450 600
Kilometers

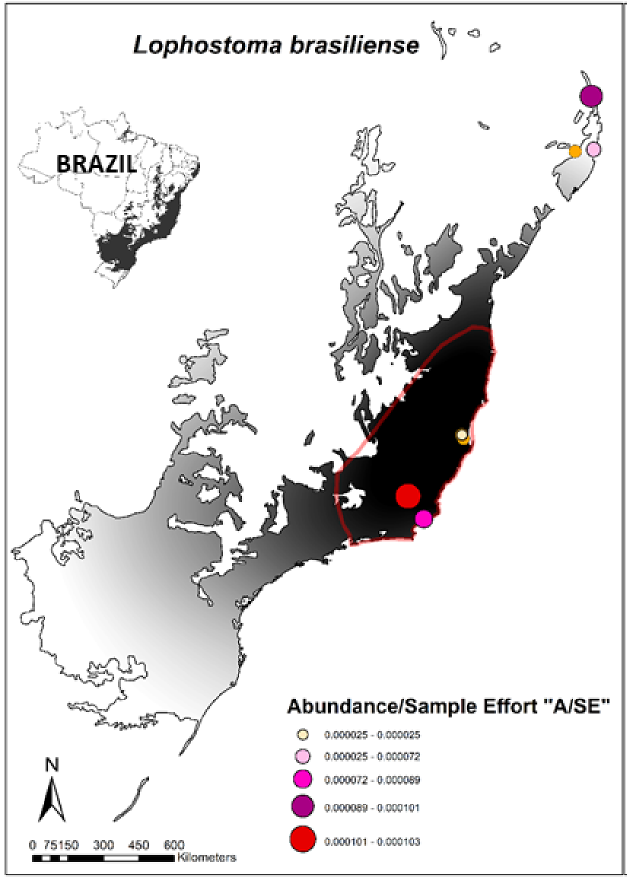

Glossophaga soricina
BRAZIL
Abundance/Sample Effort "A/SE"
0.000012 - 0.001048
0.001048 - 0.003009
0.003009 - 0.006803
0.006803 - 0.011429
0.011429 - 0.019048
N
0 75150 300 450 600
Kilometers
Glyphonycteris daviesi
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000005 - 0.000005
Glyphonycteris sylvestris
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000005 - 0.000005

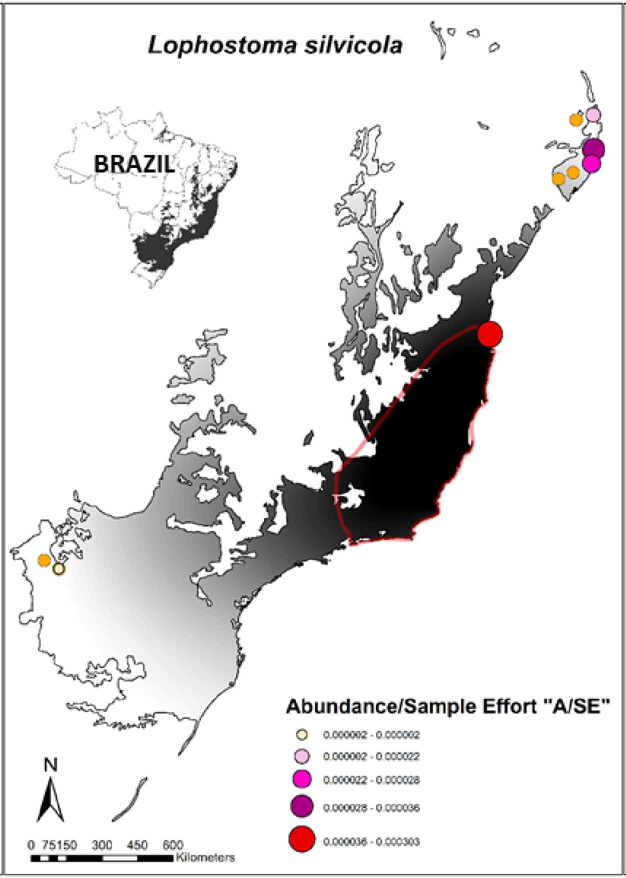
12


Lampronycteris brachyotis
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000005 - 0.000005
0.000005 - 0.000013
Lichonycteris degener
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000303 - 0.000303

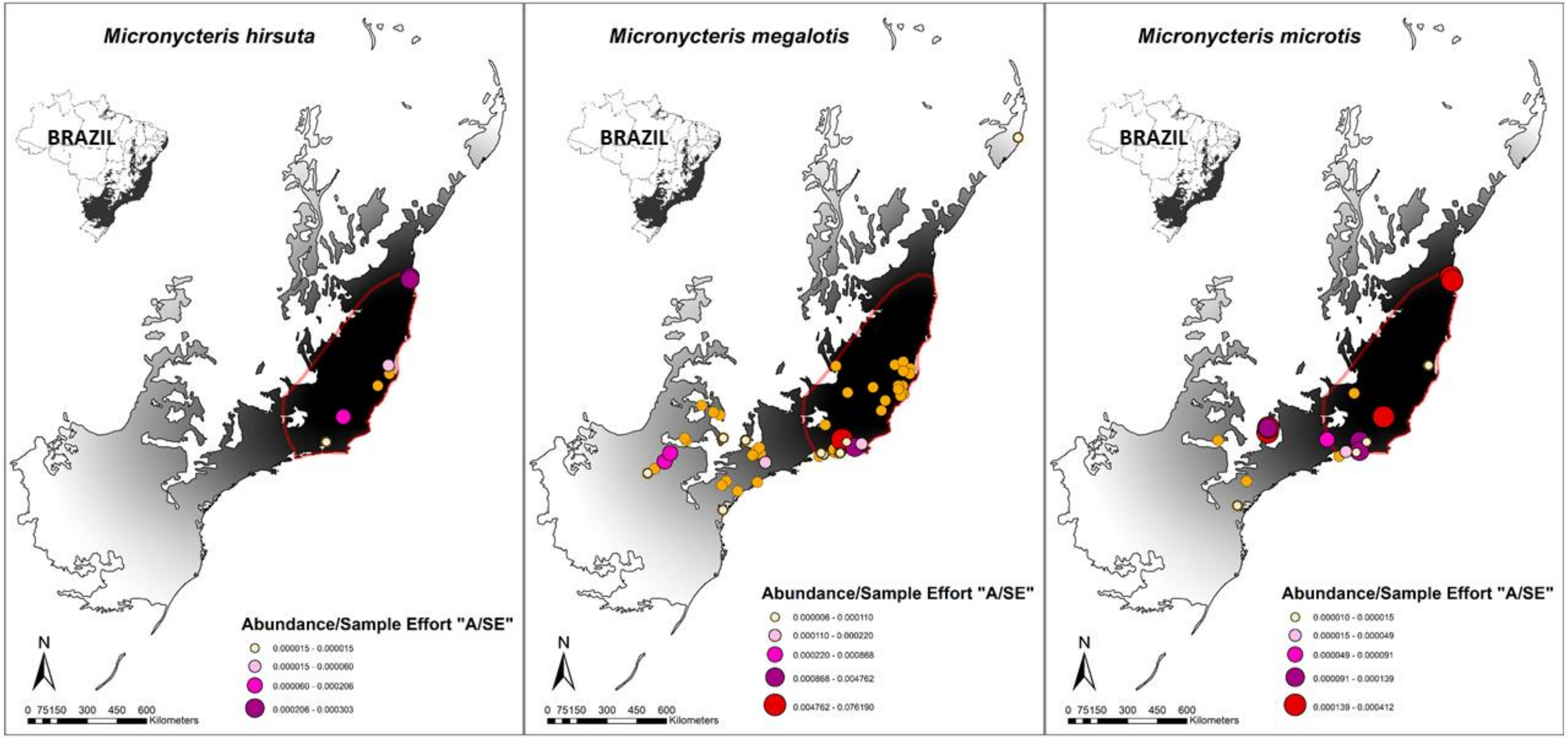
13


Lonchophylla mordax
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000303 - 0.000303
0.000303 - 0.000606
0.000606 - 0.015625
Lonchophylla peracchii
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000008 - 0.000025
0.000025 - 0.000069
0.000069 - 0.000385
0.000385 - 0.002721
0.002721 - 0.005714
Lonchorhina aurita
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000008 - 0.000008
0.000008 - 0.000016
0.000016 - 0.000036
0.000036 - 0.000156
0.000156 - 0.002381

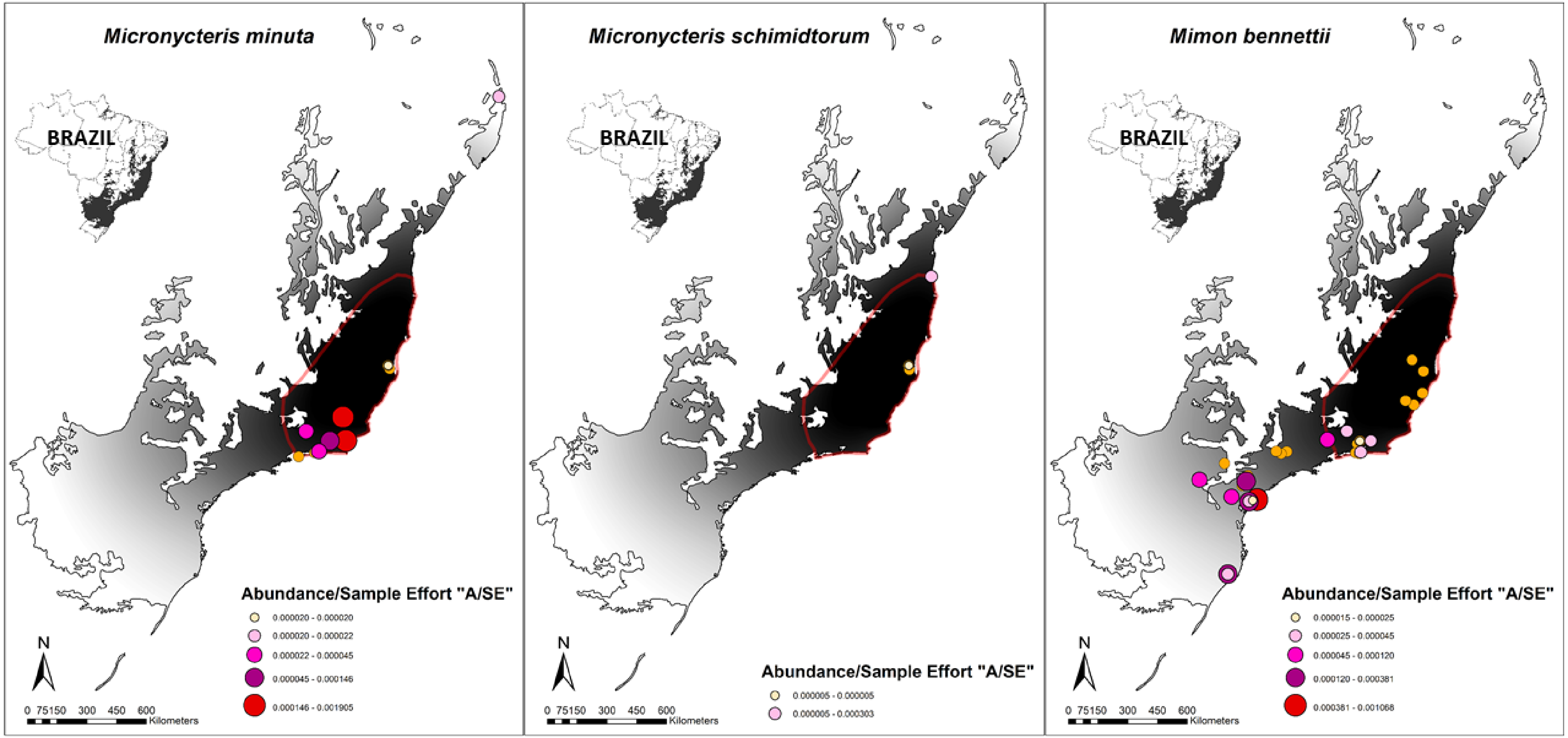

Lophostoma brasiliense
BRAZIL
Abundance/Sample Effort "A/SE"
0.000025 - 0.000025
0.000025 - 0.000072
0.000072 - 0.000089
0.000089 - 0.000101
0.000101 - 0.000103
N
0 75150 300 450 600
Kilometers

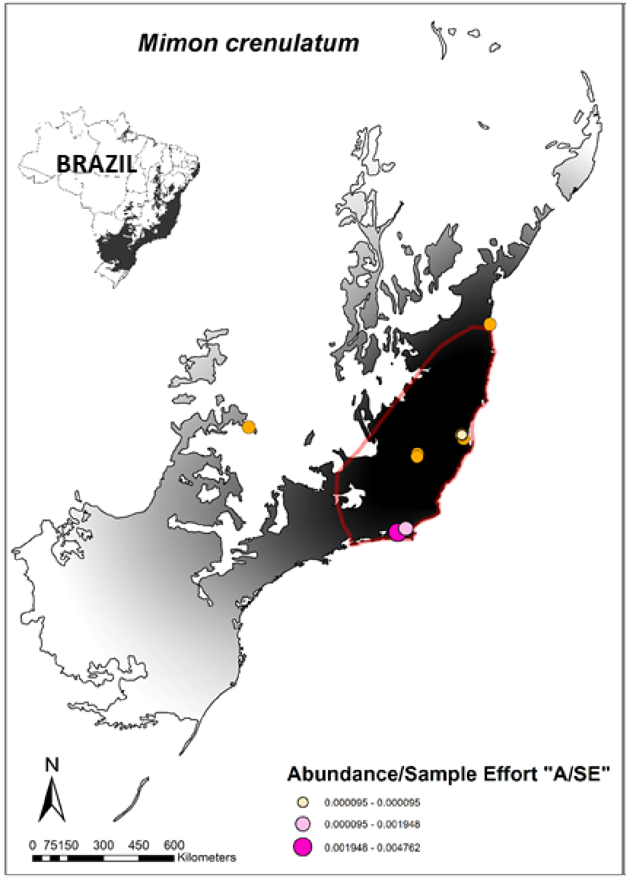

Lophostoma silvicola
BRAZIL
Abundance/Sample Effort "A/SE"
0.000002 - 0.000002
0.000002 - 0.000022
0.000022 - 0.000028
0.000028 - 0.000036
0.000036 - 0.000303
N
0 75150 300 450 600
Kilometers


Macrophyllum macrophyllum
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
Abundance_
0.000012 - 0.000012

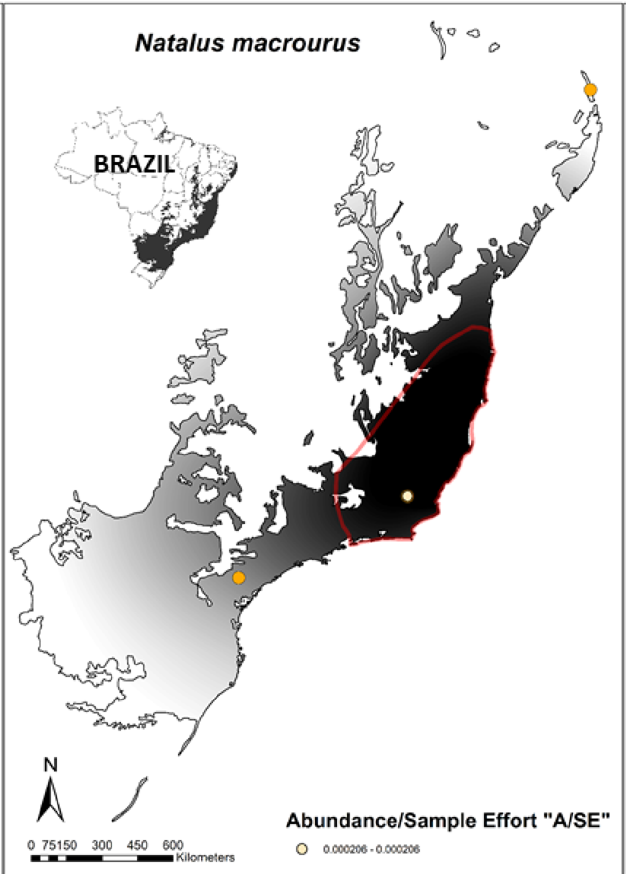

Micronycteris hirsuta
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000015 - 0.000015
0.000015 - 0.000060
0.000060 - 0.000206
0.000206 - 0.000303
Micronycteris megalotis
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000006 - 0.000110
0.000110 - 0.000220
0.000220 - 0.000868
0.000868 - 0.004762
0.004762 - 0.076190
Micronycteris microtis
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000010 - 0.000015
0.000015 - 0.000049
0.000049 - 0.000091
0.000091 - 0.000139
0.000139 - 0.000412

16

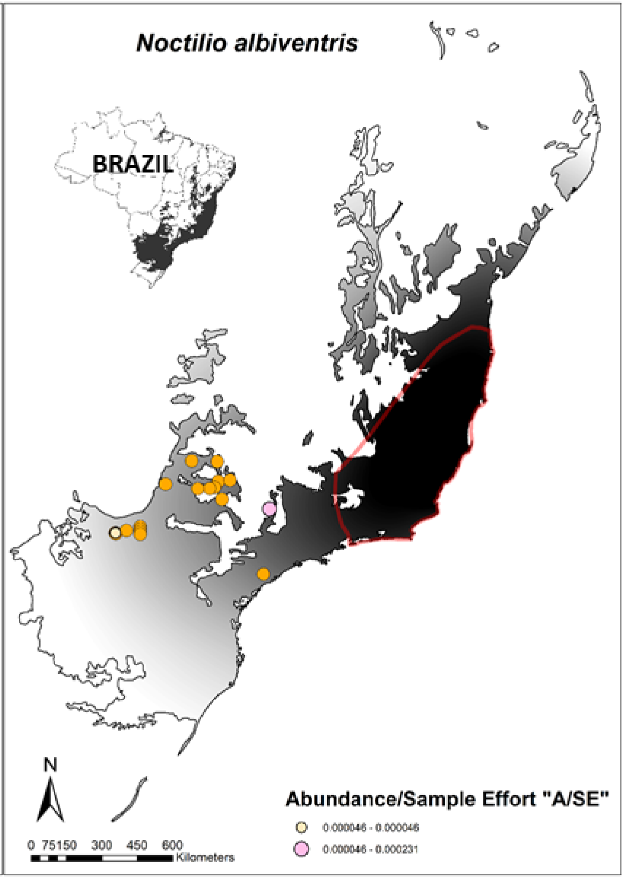

Micronycteris minuta
BRAZIL
Abundance/Sample Effort "A/SE"
0.000020 - 0.000020
0.000020 - 0.000022
0.000022 - 0.000045
0.000045 - 0.000146
0.000146 - 0.001905
N
0 75150 300 450 600
Kilometers
Micronycteris schimidtorum
BRAZIL
Abundance/Sample Effort "A/SE"
0.000005 - 0.000005
0.000005 - 0.000303
N
0 75150 300 450 600
Kilometers
Mimon bennettii
BRAZIL
Abundance/Sample Effort "A/SE"
0.000015 - 0.000025
0.000025 - 0.000045
0.000045 - 0.000120
0.000120 - 0.000381
0.000381 - 0.001068
N
0 75150 300 450 600
Kilometers



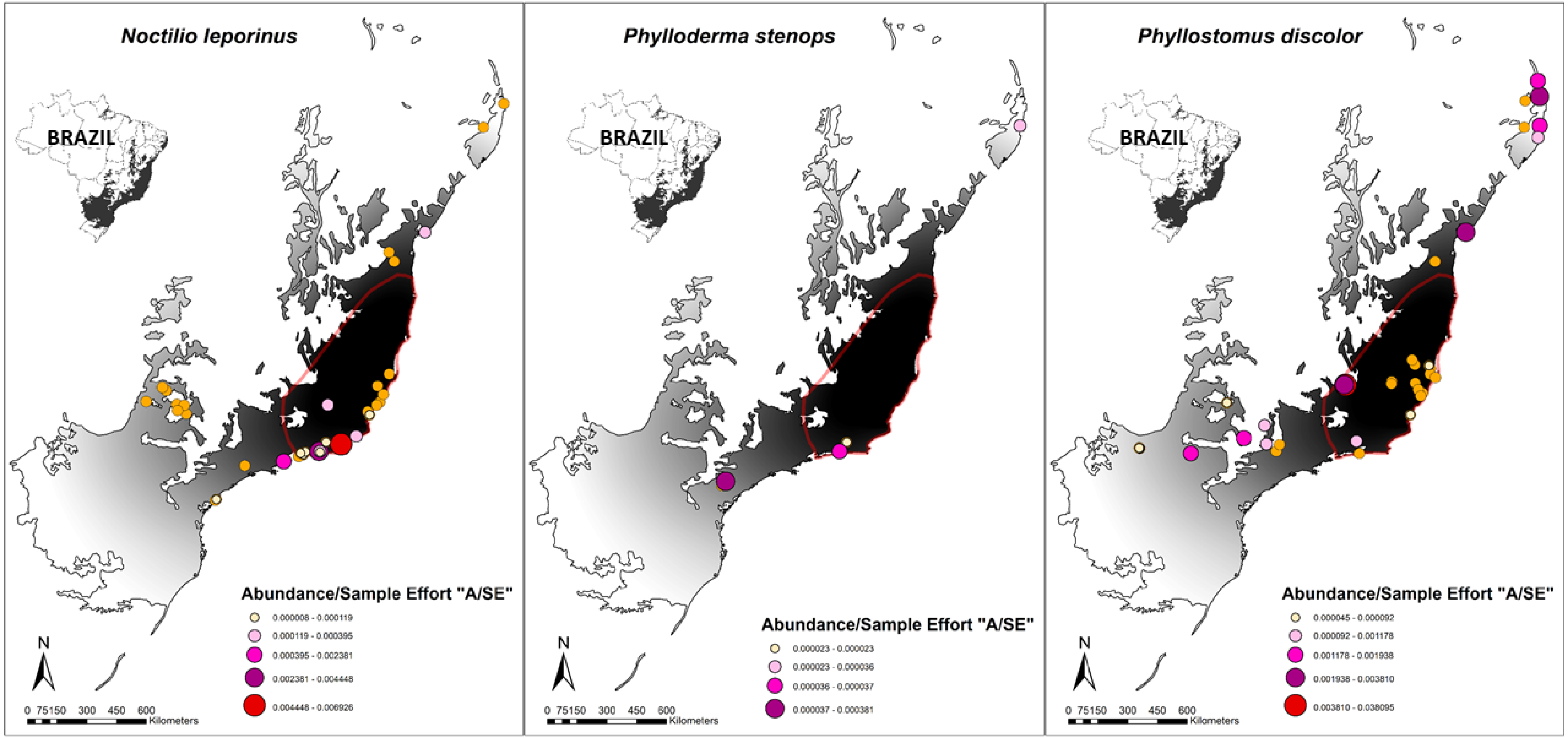
Mimon crenulatum



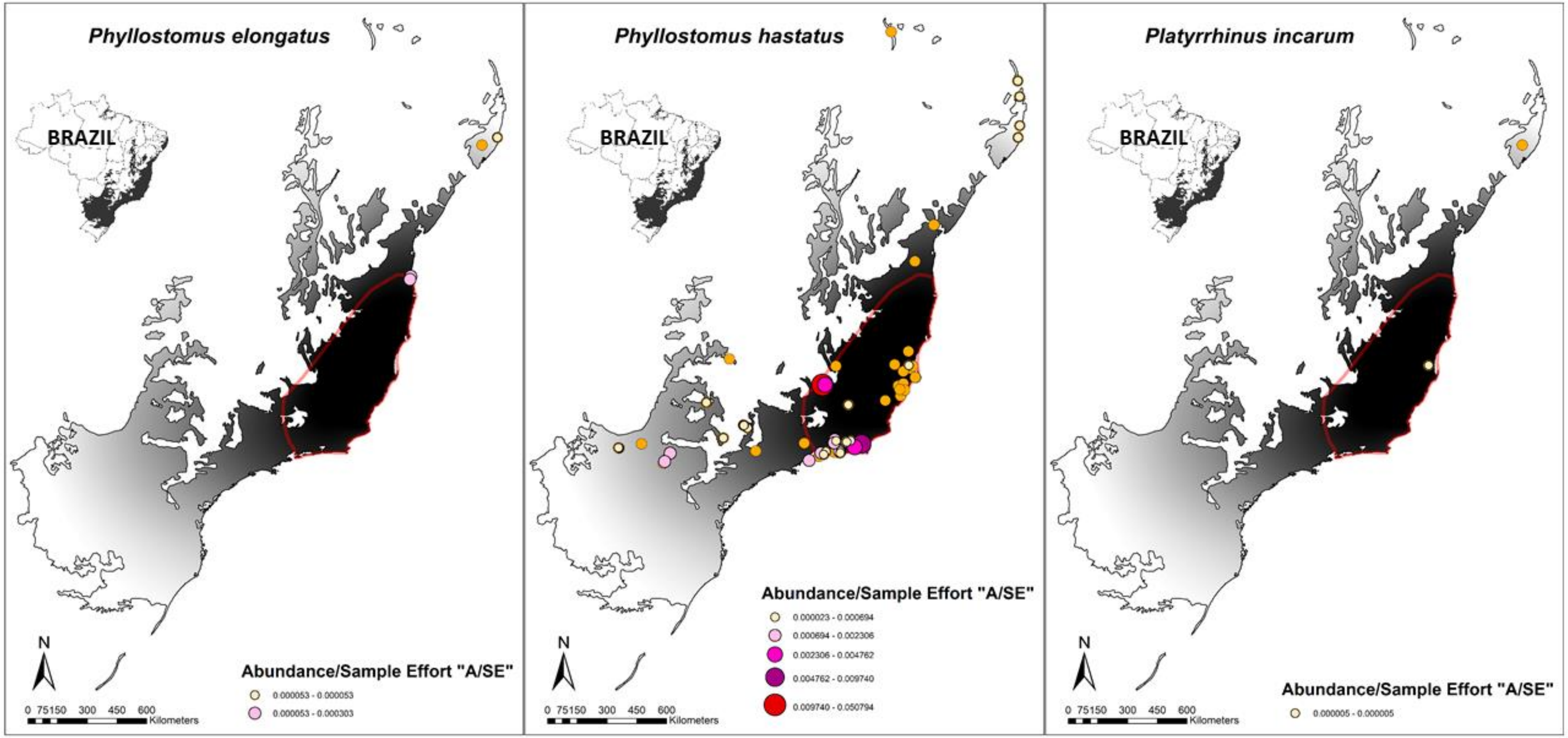
Natalus macrourus

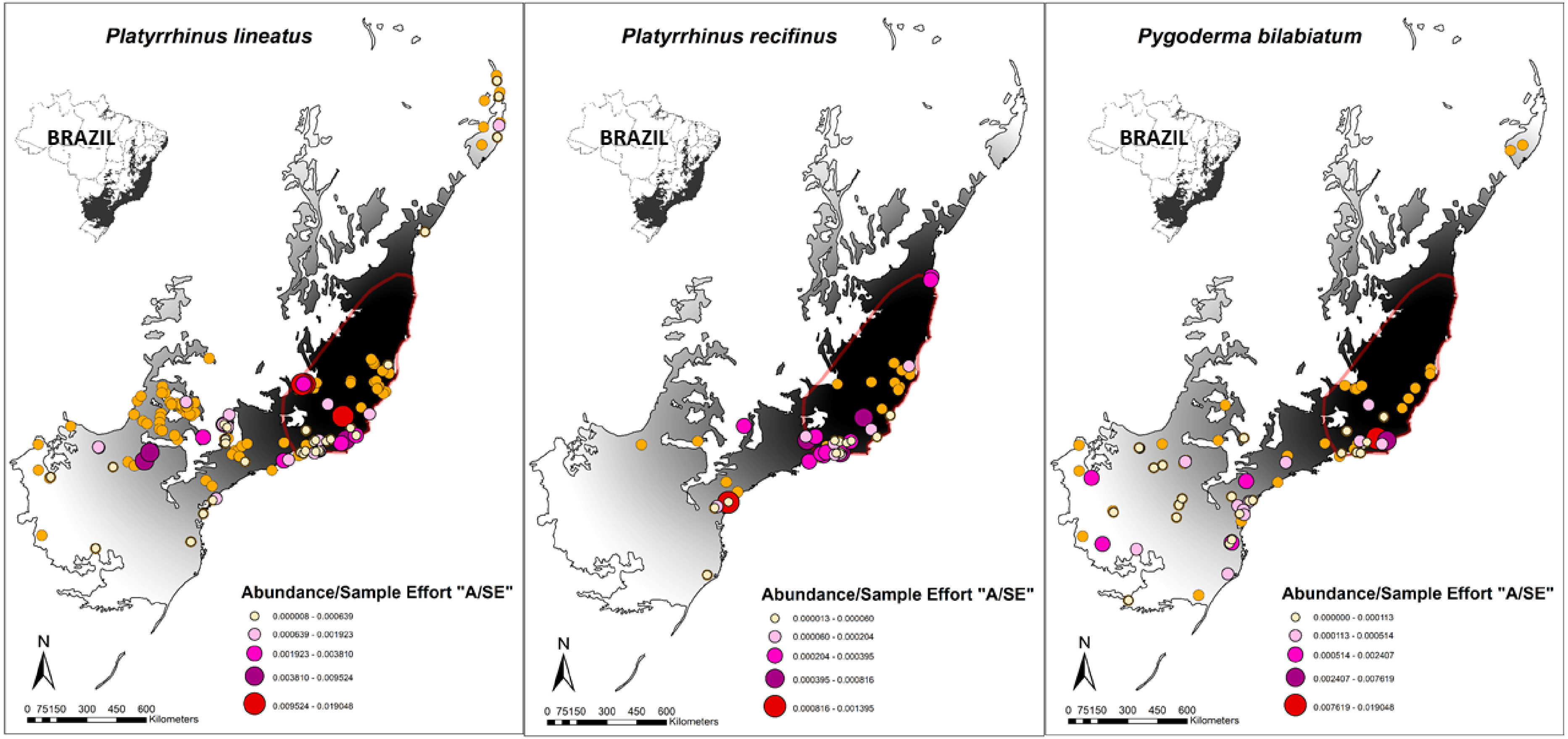


Noctilio albiventris

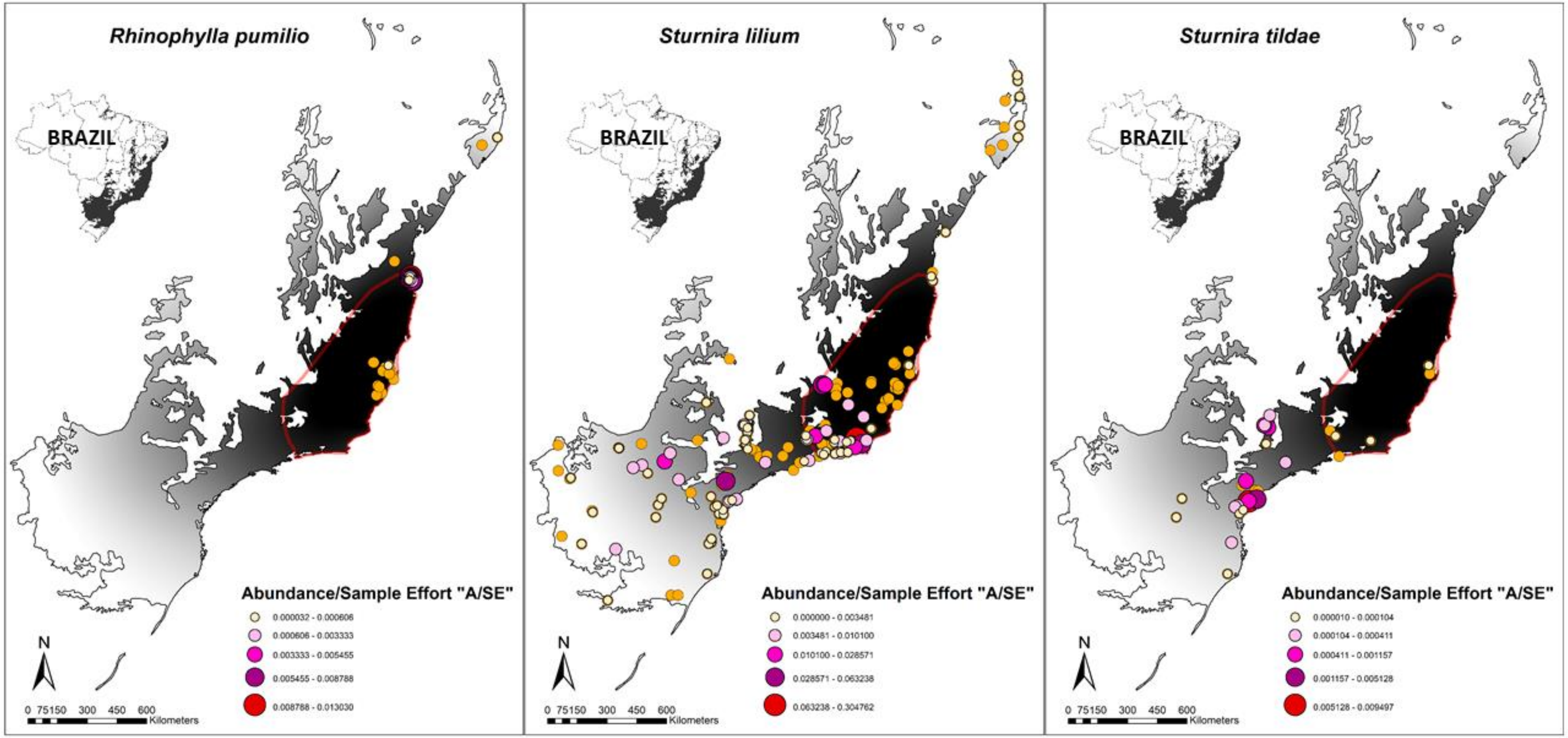

Noctilio leporinus
BRAZIL
Abundance/Sample Effort "A/SE"
0.000008 - 0.000119
0.000119 - 0.000395
0.000395 - 0.002381
0.002381 - 0.004448
0.004448 - 0.006926
N
0 75150 300 450 600
Kilometers
Phylloderma stenops
BRAZIL
Abundance/Sample Effort "A/SE"
0.000023 - 0.000023
0.000023 - 0.000036
0.000036 - 0.000037
0.000037 - 0.000381
N
0 75150 300 450 600
Kilometers
Phyllostomus discolor
BRAZIL
Abundance/Sample Effort "A/SE"
0.000045 - 0.000092
0.000092 - 0.001178
0.001178 - 0.001938
0.001938 - 0.003810
0.003810 - 0.038095
N
0 75150 300 450 600
Kilometers

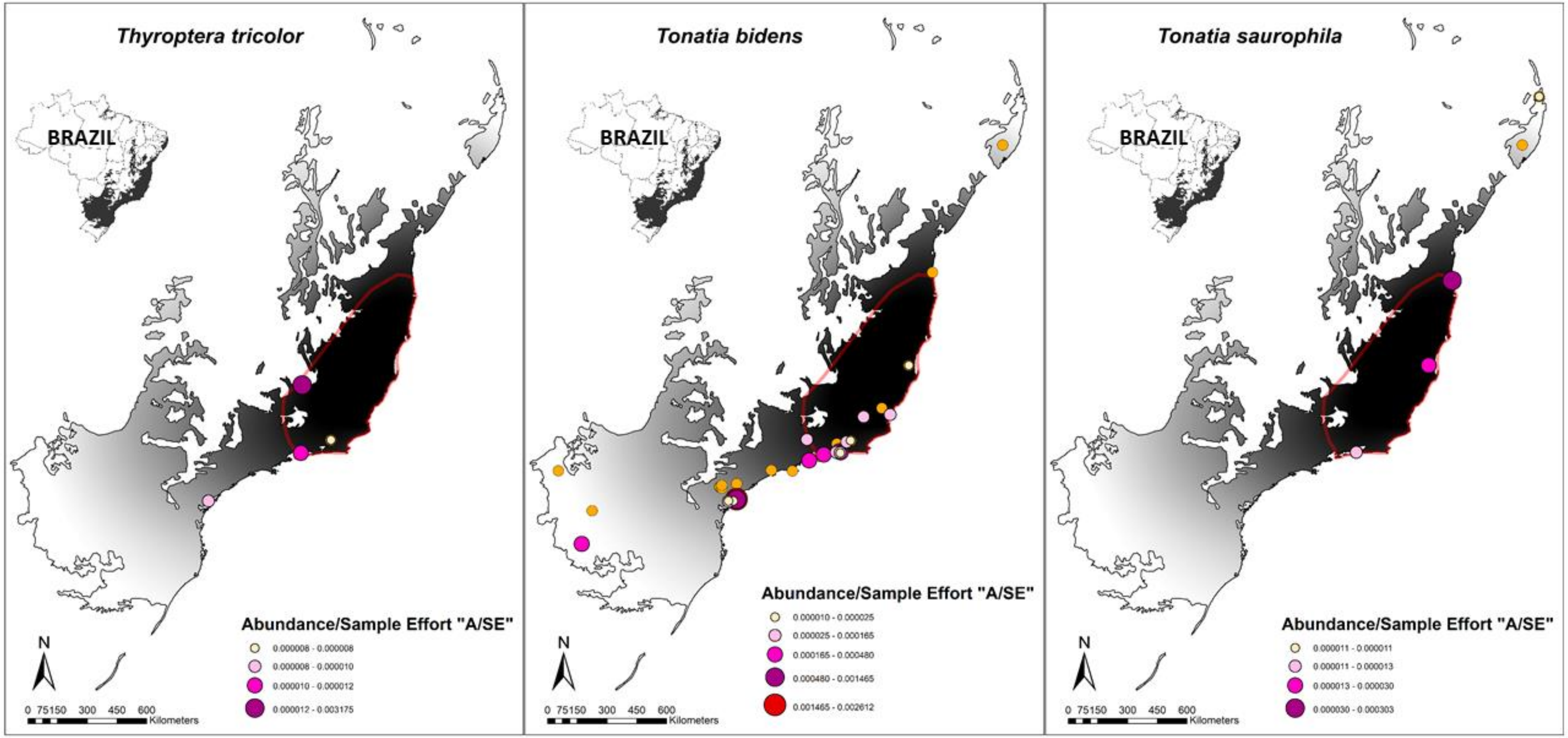
19


Phyllostomus elongatus
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000053 - 0.000053
0.000053 - 0.000303
Phyllostomus hastatus
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000023 - 0.000694
0.000694 - 0.002306
0.002306 - 0.004762
0.004762 - 0.009740
0.009740 - 0.050794
Platyrrhinus incarum
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000005 - 0.000005

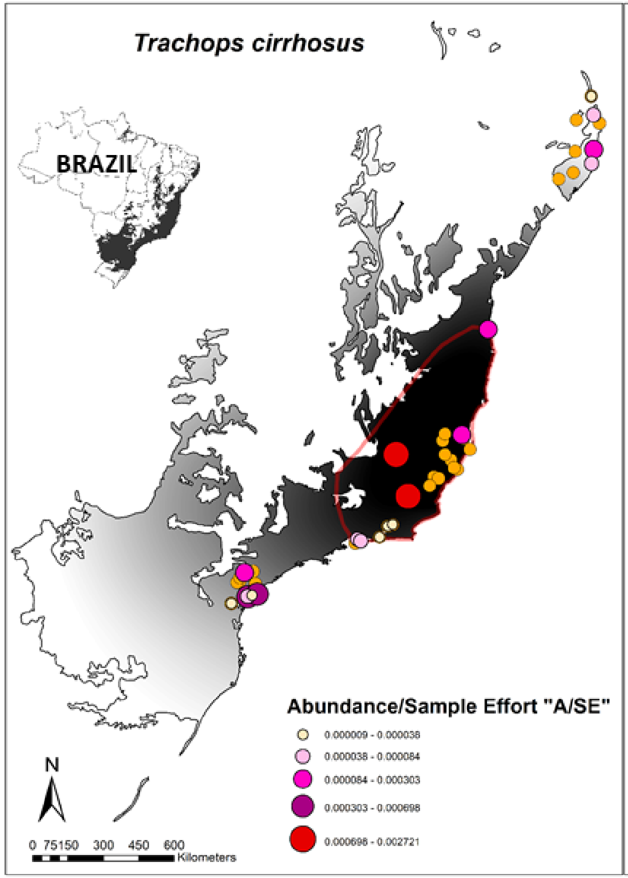

Platyrrhinus lineatus
BRAZIL
Abundance/Sample Effort "A/SE"
0.000008 - 0.000639
0.000639 - 0.001923
0.001923 - 0.003810
0.003810 - 0.009524
0.009524 - 0.019048
N
0 75150 300 450 600
Kilometers
Platyrrhinus recifinus
BRAZIL
Abundance/Sample Effort "A/SE"
0.000013 - 0.000060
0.000060 - 0.000204
0.000204 - 0.000395
0.000395 - 0.000816
0.000816 - 0.001395
N
0 75150 300 450 600
Kilometers
Pygoderma bilabiatum
BRAZIL
Abundance/Sample Effort "A/SE"
0.000000 - 0.000113
0.000113 - 0.000514
0.000514 - 0.002407
0.002407 - 0.007619
0.007619 - 0.019048
N
0 75150 300 450 600
Kilometers

21


Rhinophylla pumilio
BRAZIL
Abundance/Sample Effort "A/SE"
0.000032 - 0.000606
0.000606 - 0.003333
0.003333 - 0.005455
0.005455 - 0.008788
0.008788 - 0.013030
N
0 75150 300 450 600
Kilometers
Sturnira lilium
BRAZIL
Abundance/Sample Effort "A/SE"
0.000000 - 0.003481
0.003481 - 0.010100
0.010100 - 0.028571
0.028571 - 0.063238
0.063238 - 0.304762
N
0 75150 300 450 600
Kilometers
Sturnira tildae
BRAZIL
Abundance/Sample Effort "A/SE"
0.000010 - 0.000104
0.000104 - 0.000411
0.000411 - 0.001157
0.001157 - 0.005128
0.005128 - 0.009497
N
0 75150 300 450 600
Kilometers


Thyroptera tricolor
BRAZIL
Abundance/Sample Effort "A/SE"
0.000008 - 0.000008
0.000008 - 0.000010
0.000010 - 0.000012
0.000012 - 0.003175
N
0 75150 300 450 600
Kilometers
Tonatia bidens
BRAZIL
Abundance/Sample Effort "A/SE"
0.000010 - 0.000025
0.000025 - 0.000165
0.000165 - 0.000480
0.000480 - 0.001465
0.001465 - 0.002612
N
0 75150 300 450 600
Kilometers
Tonatia saurophila
BRAZIL
Abundance/Sample Effort "A/SE"
0.000011 - 0.000011
0.000011 - 0.000013
0.000013 - 0.000030
0.000030 - 0.000303
N
0 75150 300 450 600
Kilometers

23



Trachops cirrhosus

Trinycteris nicefori

Uroderma bilobatum

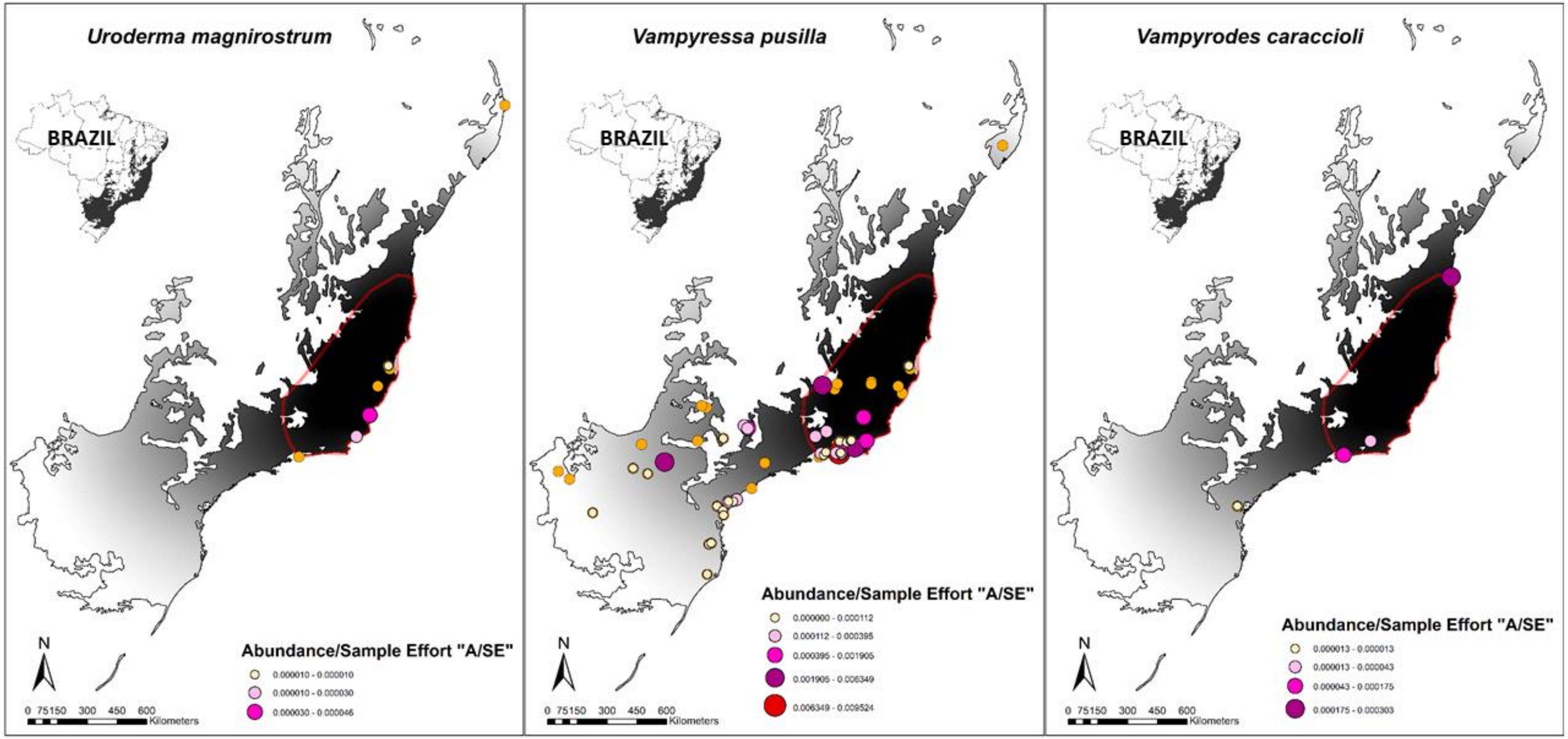

Uroderma magnirostrum
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000010 - 0.000010
0.000010 - 0.000030
0.000030 - 0.000046
Vampyressa pusilla
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000000 - 0.000112
0.000112 - 0.000395
0.000395 - 0.001905
0.001905 - 0.006349
0.006349 - 0.009524
Vampyrodes caraccioli
BRAZIL
N
0 75150 300 450 600
Kilometers
Abundance/Sample Effort "A/SE"
0.000013 - 0.000013
0.000013 - 0.000043
0.000043 - 0.000175
0.000175 - 0.000303

Table 1A. List of 59 bat species and occurrences (georefrenced locations) for all locations in the Atlantic Forest, Congruence Area and only for Protected Areas (PAs). The occurrence numbers represent the total number of georeferenced sites where each species was recorded. The table also shows other information for the species: food preference, occurrence biomes (Reis et al., 2017), conservation status (Global assessment - IUCN, 2016; National assessment- ICMBio/MMA, 2018), class of the Geographical Interpolation Endemism (GIE) and Status in the Area of Congruence. Food Preference: O / C - Omnivore / Carnivore; I - insectivore; H - hematophagous; O - Omnivorous; N - nectarivore; F - Frugivore; P - Piscivore. Occurrence in other biomes: A - Amazon; C - Cerrado; Ca - Caatinga; P - Pantanal; Pa - Pampas. Conservation status: NI – Not included; LC - Least Concern; DD - Data Deficient; NT - Near Threatened and EN - Endangered. Class GIE: class 1- radius of distribution of the species varies from 0 to 400 km; Class 2- 401 to 800 km; Class 3- from 801 to 1,200 km; Class 4- from 1,201 to 1,600 km; Class 5- from 1,601 to 2,000 km; and Class 6- and from 2,001 to 2,200 km. Status in the Congruence Area: P - present; A - absent; R - restricted.

Species	Occurrence in other biomes	Food preference	Conservation status (IUCN)	Conservation status (ICMBio/MMA)	Total Occurrences	Ocurrences in Congruence area	Total of ocurrences in PAs	Total of ocurrences in Pas in Congruence area	Occurrences in PtAs	Occurrences in PtAs in Cogruence area	Abundance/Sample Effort index "A/EA"	Class (GIE)	Status in Congruence area
Family Phyllostomidae **Subfamily Micronycterinae**													
Lampronycteris brachyotis (Dobson, 1879)	C and A	O/C	LC	NI	4	2	1	1	0	0	C	3	P
Micronycteris hirsuta (Peters, 1869)	A	I	LC	NI	8	8	3	3	0	0	C	2	R
Micronycteris megalotis (Gray, 1842)	A, C, Ca and P	I	LC	NI	58	30	11	4	6	3	C	7	P
Micronycteris microtis Miller, 1898	A and C	I	LC	NI	19	11	7	4	1	0	C	4	P

Micronycteris minuta (Gervais, 1856)	A, C, Ca and P	I	LC	NI	11	10	5	4	1	1	C	6	P
Micronycteris schmidtorum Sanborn, 1935	A, C and Ca	I	LC	NI	3	2	1	1	0	0	C	2	R
Subfamily Desmodontinae													
Desmodus rotundus (É. Geoffroy, 1810)	A, Ca, C, P and Pa	H	LC	NI	203	80	51	11	0	9	C	7	P
Diaemus youngii (Jentink, 1893)	A, Ca, C and P	H	LC	NI	22	7	7	3	3	0	C	7	P
Diphylla ecaudata Spix, 1823	A, Ca, C and P	H	LC	NI	46	26	10	3	7 0	4	C	6	P
Subfamily Lonchorhininae													
Lonchorhina aurita Tomes, 1863	A, Ca, C and P	I	LC	VU	10	3	6	0	0	0	C	5	P
Subfamily Phyllostominae													
Chrotopterus auritus (Peters, 1856)	A, Ca, C, P and Pa	C/I	LC	NI	75	18	20	5	2	2	C	7	P
Lophostoma brasiliense Peters, 1866	A, C and Ca	I	LC	NI	8	4	5	3	0	0	C	4	P
Lophostoma silvicola d'Orbigny, 1836	A, Ca, C and P	I	LC	NI	9	1	5	1	0	0	C	7	P
Macrophyllum macrophyllum (Schinz, 1821)	A, C and P	I	LC	NI	2	1	0	0	0	0	C	3	P
Mimon bennettii (Gray, 1838)	A, Ca, C and P	I	LC	NI	30	12	9	2	2	2	C	3	P
Mimon crenulatum (É. Geoffroy, 1803)	A, Ca, C and P	I	LC	NI	8	6	2	1	2	2	C	3	P
Phylloderma stenops (Peters, 1865)	A, C and P	O	LC	NI	5	2	2	0	0	0	C	6	P
Phyllostomus discolor (Wagner, 1843)	A, Ca, C and P	O	LC	NI	38	18	7	1	3	2	C	5	P
Phyllostomus elongatus (É. Geoffroy, 1810)	A, C and P	O	LC	NI	4	1	3	1	0	0	C	2	P
Phyllostomus hastatus (Pallas, 1767)	A, Ca, C and P	O	LC	NI	66	38	17	6	4	1	C	6	P
Tonatia bidens (Spix, 1823)	P, C and Ca	O	DD	NI	39	17	22	7	3	1	C	7	P
Tonatia saurophila Koopman & Williams, 1951	Ca, C and A	O	LC	NI	5	3	4	2	0	0	C	4	P
Trachops cirrhosus (Spix, 1823)	A, C, Ca and P	O	LC	NI	51	26	25	9	3	2	C	6	P
Subfamily Glossophaginae													
Anoura caudifer (É. Geoffroy, 1818)	A, C, P and Pa	N	LC	NI	79	39	26	8	7	5	C	7	P
Anoura geoffroyi Gray, 1838	A, Ca, C, P and Pa	N	LC	NI	46	24	15	3	1	1	C	7	P
Dryadonycteris capixaba Nogueira,	Ca and C	N	DD	NI	5	5	1	1	2	2	C	1	R

Lima, Peracchi & Simmons, 2012													
Glossophaga soricina (Pallas, 1766)	A, Ca, C, P and Pa	N	LC	NI	223	75	47	21	21	5	C	7	P
Lichonycteris degener Miller, 1931	A	N	LC	NI	2	1	2	1	0	0	C	2	P
Subfamily Lonchophyllinae													
Lonchophylla mordax Thomas, 1903	Ca	N	LC	NI	13	11	2	2	1	1	C	4	P
Lonchophylla peracchii Dias, Esbérard & Moratelli, 2013	Ca	N	LC	NI	22	19	9	7	0	0	C	2	P
Subfamily Carolliinae													
Carollia brevicauda (Schinz, 1821)	A, Ca, C, P	F	LC	NI	14	12	9	8	0	0	C	5	P
Carollia perspicillata (Linnaeus, 1758)	A, Ca, C, P and Pa	F	LC	NI	302	145	90	35	5	0	C	7	P
Subfamily Glyphonycterinae													
Glyphonycteris daviesi (Hill, 1964)	A	I	LC	NI	2	2	1	1	0	0	C	1	R
Glyphonycteris sylvestris Thomas, 1896	A	I	LC	NI	4	2	3	1	0	0	C	4	P
Trinycteris nicefori (Sanborn, 1949)	A	I	LC	NI	3	2	2	1	0	0	C	3	P
Subfamily Rhinophyllinae													
Rhinophylla pumilio Peters, 1865	A; C and Ca	F	LC	NI	54	44	26	24	0	0	C	4	P
Subfamily Stenodermatinae													
Dermanura cinerea Gervais, 1856	A, C and Ca	F	LC	NI	61	36	32	20	19	2	C	5	P
Artibeus fimbriatus Gray, 1838	A, Ca, C, P and Pa	F	LC	NI	150	76	35	9	15	11	C	7	P
Dermanura gnoma (Handley, 1987)	A, C and Ca	F	LC	NI	7	5	5	4	0	4	C	2	R
Artibeus lituratus (Olfers, 1818)	A, Ca, C, P and Pa	F	LC	NI	201	106	60	26	12	9	C	7	P
Artibeus obscurus (Schinz, 1821)	A, Ca, C, P and Pa	F	LC	NI	106	65	52	30	2	2	C	6	P
Artibeus planirostris (Spix, 1823)	A, Ca, C, P and Pa	F	LC	NI	89	31	34	11	5	2	C	7	P
Chiroderma doriae Thomas, 1891	C and P	F	LC	NI	60	14	25	6	1	6	C	7	P
Chiroderma villosum Peters, 1860	A, C and P	F	LC	NI	36	22	17	11	8	1	C	6	P
Platyrrhinus incarum (Thomas, 1912)	A	F	LC	NI	2	1	2	1	0	0	C	3	P
Platyrrhinus lineatus (É. Geoffroy, 1810)	A, Ca, C, P	F	LC	NI	171	72	35	10	16	5	C	7	P

	and Pa												
Platyrrhinus recifinus (Thomas, 1901)	C and Ca	F	LC	NI	55	40	15	8	3	3	C	4	P
Pygoderma bilabiatum (Wagner, 1843)	C, Ca and P	F	LC	NI	72	25	20	4	7	5	C	7	P
Sturnira lilium (É. Geoffroy, 1810)	A, Ca, C, P and Pa	F	LC	NI	179	78	45	11	13	10	C	7	P
Sturnira tildae de la Torre, 1959	A, Ca, C and P	F	LC	NI	31	7	12	2	1	0	C	4	P
Uroderma bilobatum Peters, 1866	A, Ca, C, P and Pa	F	LC	NI	5	2	2	1	0	0	C	2	P
Uroderma magnirostrum Davis, 1968	A, Ca, C, P and Pa	F	LC	NI	7	6	3	3	0	0	C	5	P
Vampyressa pusilla (Wagner, 1843)	C	F	DD	NI	62	31	19	7	5	3	C	7	P
Vampyrodes caraccioli (Thomas, 1889)	A	F	LC	NI	4	2	0	0	0	0	C	3	P
Family Noctilionidae													
Noctilio albiventris Desmarest, 1818	A, Ca, C and P	I	LC	NI	19	0	5	0	3	0	C	2	A
Noctilio leporinus (Linnaeus, 1758)	A, Ca, C and P	P	LC	NI	35	18	6	3	0	0	C	6	P
Family Furipteridae													
Furipterus horrens (Cuvier, 1828)	A, C and Ca	I	LC	NI	11	2	5	2	3	0	NC	7	P
Family Thyropteridae													
Thyroptera tricolor Spix, 1823	A	I	LC	NI	4	3	1	0	0	0	C	2	P
Family Natalidae													
Natalus macrourus (Gervais, 1856)	A, C and Ca	I	NT	VU	3	1	2	1	0	0	C	5	P

ANEXOS

ANEXO A

Apresentação das normas de formatação do periódico “Neotropical Biology and Conservation”. Disponível em: http://revistas.unisinos.br/index.php/neotropical/about/submissions#onlineSubmissions Acessado em: 20 Abril, 2020.

Author Guidelines

Submission Preparation Checklist

As part of the submission process, authors are required to check off their submission's compliance with all of the following items, and submissions may be returned to authors that do not adhere to these guidelines.

The work is original and unpublished and it is not under consideration for publication anywhere else.

The manuscript file is in Microsoft Word or RTF.

The original text must contain in the following order:

Title in the same language of the article, and in English (if the article is in English, title must also be in Portuguese). The titles (on the original language and English) must have a maximun of 240 characters including spaces.;

Abstract with no more than 20 lines, followed by at least three key-words;

Abstract in English (or in Portuguese, in case the article is written in English), following the same norms of the Abstract in the original language;

Full text, typed in Times New Roman format, font 12, and with spacing of 1,5;

Images, tables, charts and graphs must include captions in the same language of the article and in English, they must be sent separately in their original files (.jpeg, .png, .tiff), not inserted in the text, with minimal resolution of 300 dpi.

The identification of authorship of the work has been removed from the file, ensuring the journal's confidentiality criteria, if the manuscript is subjected to peer review (e.g. articles), according to instructions in Ensuring a Blind Peer Review.

Short quotations (containing less than three lines) must be incorporated into the text in quotation marks;

Long quotations (longer than three lines) must be presented in an isolated paragraph, with simple spacing, font size 11 and the left margin larger than the surrounding text (4cm).

Footnotes must be used only when strictly necessary, for information that is complementary to the text. Do not use footnotes as a substitute for a reference list.

The manuscript is in accordance to the style and bibliographic requirements described in the Author's Guideline section.

References

The list of references must only include works that are cited in the text. Reference list entries must be in alphabetical order according to the last names of the first author of each work.

References must be typed in Times New Roman (pt 12) and single spacing between lines.

References must contain the work's complete data according to the journal's rules.

Examples:

Journal articles:

SURNAME, Initial(s) name. Year of publication. Article title. Journal Title, volume(issue):initial page-final page.

Articles from publications related to events:

SURNAME, Initial(s) name. Year of publication. Title of work. In: name of conference (meeting, symposium, etc.), number of the event, city, year. Proceedings ... City, Symbol. volume:: initial page-final page.

Books:

SURNAME, Initial(s) name. Year of publication. Book title. Edition, city, publisher, the total number of pages.

Book chapters:

SURNAME, Initial(s) name. Year of publication. Chapter title. In: Initial(s) Name. SURNAME (ed.), Book title. City, publisher, initial page-final page.

Thesis and dissertations:

SURNAME, Initial(s) name. Year of publication Title of the thesis. City, state. Type of thesis (MA, PhD). University, the total number of pages.

Sites and electronic texts:

Explicit author:

SURNAME, Initial(s) name. Year of publication. Title of work. Available at: http://. Accessed on: month day, year.

Anonymous author:

SOURCE/SITE. Initial(s) name. Year of publication. Title of work. Available at: http://. Accessed on: month day, year.

Newspapers and magazines, organs and institutions:

Explicit author:

SURNAME, Initial(s) name. Year of publication. Title of work. Source (newspaper, organs, institutions, etc.). Session (Column, etc.). City, day month.

Anonymous author:

SOURCE (newspaper, organs, institutions, etc.). Year of publication. Title of work. City, day month, number page.

ANEXO B

Apresentação das normas de formatação do periódico “Journal of Biogeography”. Disponível em: https://onlinelibrary.wiley.com/page/journal/13652699/homepage/forauthors.html Acessado em: 20 Abril, 2020.

Author Guidelines

1. SUBMISSION

Authors should kindly note that submission implies that the content has not been published or submitted for publication elsewhere except as a brief abstract in the proceedings of a scientific meeting or symposium. All submissions must be concisely and clearly written in grammatically correct English.

Once the submission materials have been prepared in accordance with the Author Guidelines, manuscripts should be submitted online at https://mc.manuscriptcentral.com/jbi

The submission system will prompt authors to use an ORCID iD (a unique author identifier) to help distinguish their work from that of other researchers. Click here to find out more.

For help with submissions, please contact the Editorial Office at jbioffice@wiley.com

2. AIMS AND SCOPE

SCOPE:

The Journal of Biogeography publishes research at the intersection of biology and geography that is scientifically important and of broad general interest. We seek papers describing patterns and revealing mechanisms that shape biodiversity, through time, throughout the planet, from the deep past into the future, and from local to global scales. Diverse approaches are encouraged—including ecological, evolutionary, genomic, geographic, empirical, theoretical—considering any aspect of biogeography, from molecules to ecosystems and from microbes to plants and megafauna. Through this broad and inclusive scope, we aim for papers in Journal of Biogeography to address understudied, vexing, and urgent questions and to advance basic understanding of the origins, distributions, and fates of life on Earth.

Manuscripts submitted to Journal of Biogeography should be original and innovative, concise, well written, rigorously analyzed and argued, and consequential. While many such studies will be multifaceted, comparative, and draw generalities, we also welcome exceptional case studies that illustrate particularly interesting deviations that, in their aggregate, shift preconceptions.

The Journal of Biogeography is edited and reviewed for the community by a team of practising biogeographers. We support open data, accessibility to publish and read, and a constructive peer-review process.

VISION:

The Journal of Biogeography is the discipline's first and foremost journal. It's established history publishing influential papers in biogeography, its topical breadth, and its strong reputation in the community, provide the foundation for the journal to continue to grow as the most respected journal in the field. Nonetheless, as disciplinary and publishing trends change, to remain at the forefront of biogeography, the journal must innovate such that it represents not only core biogeography but also novel advances in emerging areas. Biogeography is an integrative discipline and the journal aims to increasingly complement its strong foundations with the most exciting multidisciplinary research.

3. MANUSCRIPT CATEGORIES AND REQUIREMENTS

The Journal publishes articles under the following main headers: 1) Research Paper, 2) Methods and Tools, 3) Data, 4) Synthesis, 5) Perspective, 6) Commentary and 7) Correspondence. All submissions are subject to peer review.

1) Research Paper. Research papers present new biogeographic research resulting from the analysis of a question in biogeography. For a typical Research paper, in which illustrative material (Tables and Figures) occupies about 3 pages of the journal when printed at final journal sizing, the text, inclusive of abstract and reference list, should not exceed 7000 words. Manuscripts should include a biosketch (see below); tables with their legends above; list of figure legends; and embedded figures, and the main headers in the main text of Research Papers should normally be Introduction, Materials and Methods, Results, Discussion, Acknowledgements, References. Methods need to be described in a manner that allows a competent practitioner in the field to repeat the study. Authors must allow repeatability by either providing a thorough description of the methods or by providing relevant computer code.

Structured abstracts. Abstracts should be of no more than 300 words, presented as a series of factual statements under the following headings: Aim, Location, Taxon, Methods, Results and Main conclusions. The Aim should give a clear statement of the principal research question(s) or hypotheses, the Taxon indicate the main group (eg angiosperms), the Methods should give details of materials/sampling/methods of analysis, and the Main conclusions should give the main take-home message.

Biosketch/Biosketches. A short Biosketch/Biosketches entry (30-100 words for one author/150 words total for the first three authors, respectively) describing the research interests of the author(s) should be provided. For papers with four or more authors, biosketch details should be supplied for the first author only and/or a general statement of the focus of the research team (which may include a link to a group web page) plus, in all cases, a statement of author contributions, e.g. Author contributions: A.S. and K.J. conceived the ideas; K.J. and R.L.M. collected the data; R.L.M. and P.A.K. analysed the data; and A.S. and K.J. led the writing.

For an example click here.

2) Methods and Tools. These are structured as in Research papers, but the main focus is to present or investigate a new method, rather than to explore a biogeographical problem. Papers in this section are expected to apply new methods

to the analysis of biogeographic data and discuss the potential of those methods for advancing the study of the field. For an example click here.

3) Data. Datasets that are likely to be of interest to the broader biogeography community are published under this category. Data papers allow scientists to publish and receive credit for work in which the nature of the collected, mobilized, or integrated data more than a specific analysis may be most impactful. The structure of a Data paper should be similar to that of a Research paper. Data papers must include a characterization of overall scope (e.g. organismal, spatial), a description of how the data were collected (protocols), a detailed characterization of all data fields and metadata, information on data records (e.g. SI or in a suitable repository), a section on technical validation, and usage notes addressing potential caveats for analysis and interpretation. Additional analyses that exemplify potential uses of the data are encouraged but not essential. Note that the Data papers category is intended for novel datasets - data used in a published or submitted research paper should be fully addressed and made available there.

4) Synthesis. Papers that have the character of a theoretical synthesis or review, even if incorporating an element of original analysis within them, should use the article type Synthesis. Guidelines are as for Research papers but submissions to the Synthesis section may be of up to 10,000 words, or exceptionally more, if the additional length is fully justified. Authors of synthesis papers are encouraged to discuss their planned paper with one of the Chief Editors, especially if the length will exceed 10,000 words. For an example click here.

5) Perspective. Perspectives papers are should be stimulating and reflective essays providing personal perspectives on key research fields and issues within biogeography. When published, Perspectives should be of no more than eight printed pages (main text maximum 5000 words; word count including abstract, main text and references 7000 words maximum but note that shorter articles are encouraged), and they should include a short, single-paragraph abstract. A biosketch (see below) may be included after the references providing the overall paper length limit is not exceeded. For an example click here.

6) Commentary. Commentary submissions should provide readily intelligible comment on the latest original research in biogeography. The prose style should be light, and the article should be written with the minimum of technical language and jargon, so as to be understandable to a general audience or an undergraduate taking an introductory course in biogeography. Contributions will be subject to rapid peer review. Commentaries should occupy a maximum of two pages of the journal, and should have a maximum of 10 references: thus the overall word count should not exceed 1600. No biosketch is included for commentaries. Should you wish to include a small figure or other illustration, this can be accommodated by a reduction in the number of words on a pro rata basis. For an example click here.

7) Correspondence. The Journal welcomes short items of correspondence prompted by papers previously published in this or occasionally in other journals. The text should not normally exceed 2500 words, inclusive of a short one-paragraph abstract (up to 150 words), and a list of 6–10 keywords. No biosketch is necessary for Correspondence papers. For an example click here.

4. PREPARING THE SUBMISSION

Article Preparation Support

Wiley Editing Services offers expert help with English Language Editing, as well as translation, manuscript formatting, figure illustration, figure formatting, and graphical abstract design – so you can submit your manuscript with confidence. Also, check out our resources for Preparing Your Article for general guidance about writing and preparing your manuscript.

Cover Letters

A cover letter to the editor, indicating in less than 100 words why this paper is of interest to the readers of the Journal, must be uploaded separately.

Parts of the Manuscript

The manuscript should be submitted in separate files: main text file with embedded figures; supporting information.

LaTeX users do not have to translate their manuscripts into MSWord, but may upload them as PDF files. Any explanatory notes, companion papers etc. for the attention of reviewers should be uploaded under 'Comments to reviewers'.

Main Text File

The text file should be single spaced, or 1.3 spaced, and presented in the following order:

i. Title

ii. A short running title of less than 40 characters

iii. The full names of the authors, only 1 corresponding author may be included

iv. The author's institutional affiliations where the work was carried out, with a footnote for the author’s present address if different from where the work was carried out

v. Acknowledgements

vi. Abstract and keywords

vii. Main text

viii. Tables embedded in the text (each table complete with title and footnotes)

ix. Figures embedded in the text, each with a figure legend

x. Data availability statement

xi. References

xii. Biosketch

xiii. Appendices (if relevant)

xiv. Supporting information should be supplied as separate files.

Title. The title should be short and informative, containing major keywords related to the content. The title should not contain abbreviations (see Wiley's best practice SEO tips).

Authorship. For details on eligibility for author listing, please refer to the journal’s Authorship policy outlined in the Editorial Policies and Ethical Considerations section. Only 1 corresponding author may be included.

Acknowledgements. Contributions from individuals who do not meet the criteria for authorship should be listed, with permission from the contributor, in an Acknowledgements section. Financial and material support should also be mentioned. Thanks to anonymous reviewers are not appropriate.

Conflict of Interest Statement. Authors will be asked to provide a conflict of interest statement during the submission process. See ‘Conflict of Interest’ section in Editorial Policies and Ethical Considerations for details on what to include in this section. Authors should ensure they liaise with all co-authors to confirm agreement with the final statement.

Abstract and Keywords

Abstracts and keywords are required for some manuscript types. For details on manuscript types that require abstracts and/or keywords, as well as how to prepare them, please refer to the ‘Manuscript Categories and Requirements’ section. Please provide 6-10 keywords, arranged alphabetically, separated by commas. Note that optimally the most important keywords are repeated in the title and the keywords.

Main Text

The journal uses British spelling; however, authors may submit using either option, as spelling of accepted papers is converted during the production process.

References

References are styled according to the sixth edition of the Publication Manual of the American Psychological Association. List all sources in the reference alphabetically by name.

In text citations should follow the author-date method. This means that the author's last name and the year of publication for the source should appear in the text, for example, (Jones, 1998), and a complete reference should appear in the reference list at the end of the paper.

When a work has two authors, cite both names every time the reference occurs in text. When a work has three, four, or five authors, cite all authors the first time the reference occurs; subsequent citations include only the surname of the first author followed by et al., (not Italicized and with a period after “al.”) and the year if it is the first citation of the reference within a paragraph.

If there are two or more citations that shorten to the same lead author and date, give as many additional names as needed to identify them, e.g., (Smith, Jones, et al., 1991) and (Smith, Burke, et al., 1991).

Unpublished data, works in preparation and papers submitted but not yet accepted may be cited in the text as personal communication, giving the author's initials and surname, but should not be included in the reference list. It is the author's responsibility to obtain permission from colleagues to include their work as a personal communication. Please add the person's initials, surname and if applicable institute for personal communications.

The basic reference form for a journal paper is: Author (date).Paper title. Journal, Volume, page; and for a book citation: Author (date). Book title. Place of publication, publisher.

Please note that for journal articles, issue numbers are not included unless each issue in the volume begins with page one. Journals names are written out in full.

Please ensure that in the paper titles only proper names are capitalized, and that all scientific binomials are in italics.

Please include up to seven authors in the list (use "&" before last author name). For eight or more authors please list the first six and then use ellipses followed by last author (do not use "&" before last author name)

Journal article:

Light, M. A., & Light, I. H. (2008). The geographic expansion of Mexican immigration in the United States and its implications for local law enforcement. Law Enforcement Executive Forum Journal, 8(1), 73–82.

Book:

Goldstein, H. (1990). Problem-oriented policing. New York, NY: McGraw-Hill. Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis (2nd ed.). Thousand Oaks, CA: Sage.

Edited Book:

Gilbert, D. G., McClernon, J. F., Rabinovich, N. E., Sugai, C., Plath, L. C., Asgaard, G., ... Botros, N. (1983). Situational crime prevention: Its theoretical basis and practical scope. In M. Tonry & N. Morris (Eds.), Crime and justice: An annual review of research (Vol. 4, pp. 225–256). Chicago, IL: University of Chicago Press.

Citations to data sources

Some studies (e.g., meta-analyses) use data drawn from multiple published sources. If these sources are not otherwise cited in the main text, they should be listed in one or more appendices with titles similar to the following: "Appendix 1 – Data sources". These data appendices will be printed in the main paper (so that citation indexing services will capture them), but in a reduced font. These appendices should be cited in the main text (e.g. "A list of the data sources is found in Appendix 1."), and be placed after the biosketch in the manuscript.

Tables

Tables should be self-contained and complement, not duplicate, information contained in the text. They should be supplied as editable files, not pasted as images. Legends should be concise but comprehensive – the table, legend, and footnotes must be understandable without reference to the text, giving the study organism and study location and 'n' values where applicable. Column headings should be brief, with units of measurement in parentheses. All abbreviations must be defined in footnotes.

Figure Legends

Legends should be concise but comprehensive – the figure and its legend must be understandable without reference to the text, to this end both the geographical region and the taxon should be mentioned in each caption. Include definitions of any symbols used and define/explain all abbreviations and units of measurement.

Figures

For review purposes, figures should be embedded in the text file. All illustrations (including photographs and maps) are classified as figures and they should be numbered consecutively as first cited in the text. Panels should be labelled (a), (b), (c), etc. rather than (A), (B), (C) etc. and referred to in the text as, for example, Fig. 1a. Figure legends should be listed at the end of the paper before the embedded figures. Legends should be explicit and informative and should ‘stand alone’ from the main text, giving the study organism and study location where applicable. All abbreviations should be defined.

Click here for the basic figure requirements for figures submitted with manuscripts for initial peer review, as well as the more detailed post-acceptance figure requirements.

If and when your paper is accepted for publication, the editorial office will request you to upload your figures as separate files in the format(s) specified below. When supplying these files, use the following naming convention: manuscript number, figure number and then the appropriate file extension e.g. 'JBI-08-0500_Fig1.tif'.

Photographic figures should be saved in .tif format at 300 d.p.i. (or failing that in .jpg format with low compression). Line figures should be saved as vector graphics (i.e. composed of lines, curves, points and fonts) in .eps or .pdf format, as this enhances their display when published online. Combination figures (those composed of vector and pixel/raster elements) should also be saved in .eps or .pdf format where possible. If line figures and combination figures cannot be saved in vector graphics format, they should be saved in .tif format at high resolution (i.e. 600–800 d.p.i.) (do not save them in .jpg format). If you are unsure about the resolution of your .tif files, please zoom in and check that fonts, curves and diagonal lines are smooth-edged and do not appear blocky. Note that .tif files are downsampled for online publication and so authors should preferentially opt for vector graphic formats for line and combination figures (full resolution .tif files are used for print publication). Colour figures should be saved in CYMK rather than RGB.

Prepare figures such that, after reduction to print size, all lettering and symbols will be clear and easily read, and such that each figure makes effective use of space. Font size in figures should be 8 pt. To check this, fix the image size in Illustrator to the required column width, and check the font size. Possible figure sizes: single column = 79mm, 2/3rd column = 110mm, double column = 168mm, maximum height of figure = 230mm.

Bar scales for maps and photographs are preferred to numerical scales and must be given on all such items. Maps that display area data and organism distribution at a continental, hemispheric, or world scale must always use an equal-area map projection (e.g. Mollweide or Aitoff's). Note especially that Mercator's projection is not acceptable for such data. Please indicate the precise projection employed in the caption. On these maps, the equatorial scale should be indicated, while scale information should be provided, preferably as a scale bar within the figure, for all maps of whatever size and area; use ‘km’ or ‘kilometres’, not ‘kilometers’. Maps should include adequate geo-referencing information (preferably the latitude and longitude).

Additional Files

Supporting Information

Supporting information is information that is not essential to the article, but provides greater depth and background. It is hosted online and appears without editing or typesetting. It may include tables, figures, videos, datasets, etc. Click here for Wiley’s FAQs on supporting information.

Note: if data, scripts, or other artefacts used to generate the analyses presented in the paper are available via a publicly available data repository, authors should include a reference to the location of the material within their paper.

Such supporting information should be referred to in the text as, for example, 'see Appendix S1 in Supporting Information'; subsequent mention should be in the form 'see Appendix S2'. Figures and tables in the Supporting Information must be numbered consecutively by Appendix number and figure number: e.g. the first figure in Appendix 1 as Fig. S1.1, the first in Appendix 2 as Fig. S2.2 (if there is only one figure in Appendix 1). All appendices, figures and tables must be cited in the text.

Supporting Information files are hosted by the Publisher in the format supplied by the author and are not copy-edited by the Publisher. It is the responsibility of the author to supply Supporting Information in an appropriate file format and to ensure that it is accurate and correct. Authors should therefore prepare Supporting Information with the same rigour as their main paper, including adherence to journal style (e.g. formatting of references, figure captions, headings). Sources cited only in the Supporting Information should be listed in a reference section within the supplementary files and not with the main paper. Supporting Information can be provided as separate editable files or, preferably, as one combined file. Authors are discouraged from supplying very large files or files in non-standard file formats, both of which may reduce their use to the readership. At the point a paper is accepted, these files should be prepared without line numbers or wide line spacing, and with all track-change edits accepted.

General Style Points

The following points provide general advice on formatting and style.

Abbreviations: In general, terms should not be abbreviated unless they are used repeatedly and the abbreviation is helpful to the reader. Initially, use the word in full, followed by the abbreviation in parentheses. Thereafter use the abbreviation only.

Units of measurement: Measurements should be given in SI or SI-derived units. Visit the Bureau International des Poids et Mesures (BIPM) website at www.bipm.fr for more information about SI units.

Numbers: numbers under 10 are spelt out, except for: measurements with a unit (8mmol/l); age (6 weeks old), or lists with other numbers (11 dogs, 9 cats, 4 gerbils).

Computer programs: All software programs should be written in small caps, first written in roman (e.g. MrBayes or BEAST) and then saved as small caps, followed at first mention by the version number and reference. Packages in R should in roman and quotations (e.g. 'vegan') and the relevant reference provided.

Wiley Author Resources

Manuscript Preparation Tips: Wiley has a range of resources for authors preparing manuscripts for submission available here. In particular, authors may benefit from referring to Wiley's best practice tips on Writing for Search Engine Optimization.

Editing, Translation, and Formatting Support: Wiley Editing Services can greatly improve the chances of a manuscript being accepted. Offering expert help in English language editing, translation, manuscript formatting, and figure preparation, Wiley Editing Services ensures that the manuscript is ready for submission.

Guidelines for Cover Image Submissions: If you would like to send suggestions for artwork related to your manuscript to be considered to appear on the cover of the journal, please follow these general guidelines.

5. EDITORIAL POLICIES AND ETHICAL CONSIDERATIONS

Editorial Review and Acceptance

The acceptance criteria for all papers are the quality and originality of the research and its significance to journal readership. Papers will only be sent to review if the Editor-in-Chief determines that the paper meets the appropriate quality and relevance requirements.

Wiley's policy on confidentiality of the review process is available here.

Referrals to the Open Access Journal "Ecology and Evolution" and "Geo: Geography and Environment"

This Journal works together with Wiley's Open Access journals, Ecology and Evolution and Geo: Geography and Environment, to enable rapid publication of good quality research that we are unable to accept for publication. Authors may be offered the option of having their paper, along with any related reviews, automatically transferred for consideration by the Editors of Ecology and Evolution or Geo: Geography and Environment. Authors will not need to reformat or rewrite their manuscript at this stage, and publication decisions will be made a short time after the transfer takes place. The Editors of Ecology and Evolution and Geo: Geography and Environment will accept submissions that report well-conducted research and which reach the standard acceptable for publication. Accepted papers can be published rapidly, typically within 15 days of acceptance. Ecology and Evolution and Geo: Geography and Environment are Wiley Open Access journals and article publication fees apply. More information can be found here. Occasionally we refer papers to our sister journals DDI or GEB.

Data Storage and Documentation

Journal of Biogeography supports open research, therefore as a condition for publication, requires that the data supporting the results in the paper will be archived in an appropriate public repository, such as Dryad, TreeBASE, NERC data centre, GenBank, figshare or another archive of the author’s choice that provides comparable access and guarantee of preservation. Authors are required to provide a data availability statement, including a link to the repository they have used, and to cite the data they have shared. Whenever possible the scripts and other artefacts used to generate the analyses presented in the paper should also be publicly archived in a repository Exceptions may be granted at the discretion of the editor. If authors are unable to share data (for example, if sharing data compromises ethical standards or legal requirements) then authors are not required to share it and must describe restrictions in their data availability statement.

Data Sharing with Dryad

Journal of Biogeography have partnered with Dryad to enable authors to store and share their data without charge. The cost of depositing data of up to 20GB will be covered, should authors choose Dryad as their preferred public repository, upon acceptance of an article in Journal of Biogeography. For more details, please see the Dryad webpage here.

Preprints

The Journal of Biogeography will consider for review articles previously available as preprints on non-commercial servers. Authors may also post the submitted version of a manuscript to non-commercial servers at any time. Authors are requested to update any pre-publication versions with a link to the final published article.

Sequence Data

Sequence data have to be submitted in electronic form to any one of the three major collaborative databases: DDBJ, EMBL, or GenBank. The suggested wording for referring to accession-number information is: ‘These sequence data have been submitted to the DDBJ/EMBL/GenBank databases under accession number U12345’. Addresses are as follows:

DNA Data Bank of Japan (DDBJ) www.ddbj.nig.ac.jp

EMBL Nucleotide Archive: ebi.ac.uk/ena

GenBank www.ncbi.nlm.nih.gov/genbank

Collecting permission and the Nagoya Protocol

Authors must ensure that any data utilised in the submitted manuscript have been lawfully acquired in accordance with The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization to the Convention on Biological Diversity. It is recommended that it is explicitly stated that the relevant fieldwork permission was obtained, and to list the permit numbers, in Materials and Methods or the Acknowledgements.

Species Names

Upon its first use in the title, abstract, and text, the common name of a species should be followed by the scientific name (genus, species) in parentheses. For well-known species, however, scientific names may be omitted from article titles. If no common name exists in English, only the scientific name should be used. For the focal species in the study, the authority(ies) should be provided at the first mention in the main text, in the format specified by the relevant code.

Conflict of Interest

The journal requires that all authors disclose any potential sources of conflict of interest. Any interest or relationship, financial or otherwise that might be perceived as influencing an author's objectivity is considered a potential source of conflict of interest. These must be disclosed when directly relevant or directly related to the work that the authors describe in their manuscript. Potential sources of conflict of interest include, but are not limited to: patent or stock ownership, membership of a company board of directors, membership of an advisory board or committee for a company, and consultancy for or receipt of speaker's fees from a company. The existence of a conflict of interest does not preclude publication. If the authors have no conflict of interest to declare, they must also state this at submission. It is the responsibility of the corresponding author to review this policy with all authors and collectively to disclose with the submission ALL pertinent commercial and other relationships.

Funding

Authors should list all funding sources in the Acknowledgements section. Authors are responsible for the accuracy of their funder designation. If in doubt, please check the Open Funder Registry for the correct nomenclature: https://www.crossref.org/services/funder-registry/

Authorship

The list of authors should accurately illustrate who contributed to the work and how. All those listed as authors should qualify for authorship according to all of the following criteria:

Have made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data;

Been involved in drafting the manuscript or revising it critically for important intellectual content;

Given final approval of the version to be published. Each author should have participated sufficiently in the work to take public responsibility for appropriate portions of the content; and

Agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Contributions from anyone who does not meet the criteria for authorship should be listed, with permission from the contributor, in an Acknowledgements section (for example, to recognize contributions from people who provided technical help, collation of data, writing assistance, acquisition of funding, or a department chairperson who provided general support). Prior to submitting the article all authors should agree on the order in which their names will be listed in the manuscript.

Additional Authorship Options: Joint first or senior authorship: In the case of joint first authorship, a footnote should be added to the author listing, e.g. ‘X and Y should be considered joint first author’ or ‘X and Y should be considered joint senior author.’

ORCID

As part of the journal’s commitment to supporting authors at every step of the publishing process, the journal requires the submitting author (only) to provide an ORCID iD when submitting a manuscript. This takes around 2 minutes to complete. Find more information here.

Publication Ethics

This journal is a member of the Committee on Publication Ethics (COPE). Note this journal uses iThenticate’s CrossCheck software to detect instances of overlapping and similar text in submitted manuscripts. Read the Top 10 Publishing Ethics Tips for Authors here. Wiley’s Publication Ethics Guidelines can be found at authorservices.wiley.com/ethics-guidelines/index.html.

6. AUTHOR LICENSING

If a paper is accepted for publication, the author identified as the formal corresponding author will receive an email prompting them to log in to Author Services, where via the Wiley Author Licensing Service (WALS) they will be required to complete a copyright license agreement on behalf of all authors of the paper.

Authors may choose to publish under the terms of the journal’s standard copyright agreement, or OnlineOpen under the terms of a Creative Commons License.

General information regarding licensing and copyright is available here. To review the Creative Commons License options offered under OnlineOpen, please click here. (Note that certain funders mandate a particular type of CC license be used; to check this please click here.)

Self-Archiving Definitions and Policies: Note that the journal’s standard copyright agreement allows for self-archiving of different versions of the article under specific conditions. Please click here for more detailed information about self-archiving definitions and policies.

Open Access fees: Authors who choose to publish using OnlineOpen will be charged a fee. A list of Article Publication Charges for Wiley journals is available here.

Funder Open Access: Please click here for more information on Wiley's compliance with specific Funder Open Access Policies.

7. PUBLICATION PROCESS AFTER ACCEPTANCE

Accepted Article Received in Production

When an accepted article is received by Wiley's production team, the corresponding author will receive an email asking them to login or register with Wiley Author Services. The author will be asked to sign a publication license at this point.

Proofs

Once the paper is typeset, the author will receive an email notification with the URL to download a PDF typeset page proof, as well as associated forms and full instructions on how to correct and return the file.

Please note that the author is responsible for all statements made in their work, including changes made during the editorial process – authors should check proofs carefully. Note that proofs should be returned within 48 hours from receipt of first proof.

At proof correction stage authors will be given access to their Supporting Information (via the web) and should check it for accuracy and updates. If changes are required, corrected versions of the files that were received with the proof must be emailed to the Production Editor, with a brief description of the changes made. Supporting Information must be checked alongside the main proof and corrections for both returned to the Production Editor at the same time.

Social Media Promotion

To share your new publication on social media, information and an image for tweets, facebook, and instagram will be invited immediately prior to publication.

Publication Charges

Colour figures may be published online free of charge; however, the journal charges for publishing figures in colour in print. If the author supplies colour figures, they will be sent a Colour Work Agreement once the accepted paper moves to the production process. If the Colour Work Agreement is not returned by the specified date, figures will be converted to black and white for print publication.

Please note that the vast majority of readers access the digital versions of the journal; printed copies are increasingly rare. For the convenience of readers, we ask that you design your colour artwork so that it can be understood as best as possible in greyscale. Note that the same figure file must be used for both the print and online versions (we do not accept differing colour and black-and-white versions of the same figure).

Early View

The journal offers rapid publication via Wiley's Early View service. Early View (Online Version of Record) articles are published on Wiley Online Library before inclusion in an issue. Note there may be a delay after corrections are received before the article appears online, as Editors also need to review proofs. Once the article is published on Early View, no further changes to the article are possible. The Early View article is fully citable and carries an online publication date and DOI for citations.

8. DATA PROTECTION

By submitting a manuscript to or reviewing for this publication, your name, email address, and affiliation, and other contact details the publication might require, will be used for the regular operations of the publication, including, when necessary, sharing with the publisher (Wiley) and partners for production and publication. The publication and the publisher recognize the importance of protecting the personal information collected from users in the operation of these services, and have practices in place to ensure that steps are taken to maintain the security, integrity, and privacy of the personal data collected and processed. You can learn more at https://authorservices.wiley.com/statements/data-protection-policy.html.

9. POST PUBLICATION

Article Promotion Support

Wiley Editing Services offers professional video, design, and writing services to create shareable video abstracts, infographics, conference posters, lay summaries, and research news stories for your research – so you can help your research get the attention it deserves.

Access and Sharing

Please review Wiley's guidelines on sharing your research here.

When the article is published online:

The author receives an email alert (if requested).

The link to the published article can be shared through social media.

The author will have free access to the paper (after accepting the Terms & Conditions of use, they can view the article).

The corresponding author and co-authors can nominate up to ten colleagues to receive a publication alert and free online access to the article.

Print copies of the article can now be ordered (instructions are sent at proofing stage or use the below contact details). Email www.sheridan.com/wiley/eoc

To find out how to best promote an article, click here.

Measuring the Impact of an Article

Wiley also helps authors measure the impact of their research through specialist partnerships with Kudos and Altmetric.

10. EDITORIAL OFFICE CONTACT DETAILS

jbioffice@wiley.com

Author Guidelines updated December 2019

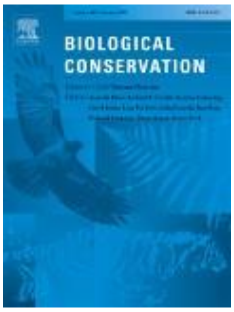
ANEXO C

Apresentação das normas de formatação do periódico “Biological Conservation”. Disponível em: https://www.elsevier.com/wps/find/journaldescription.cws_home/405853?generatepdf=true Acessado em: 20 Abril, 2020.

BIOLOGICAL CONSERVATION

AUTHOR INFORMATION PACK

TABLE OF CONTENTS



ISSN: 0006-3207

1 DESCRIPTION

Biological Conservation is a leading international journal in the discipline of **conservation science**. The journal publishes articles spanning a diverse range of fields that contribute to the biological, sociological, ethical and economic dimensions of **conservation**. The primary aim of *Biological Conservation* is the publication of high-quality papers that advance the science and practice of conservation, or which demonstrate the application of conservation principles and policy. *Biological Conservation* invites the submission of research articles, reviews (including systematic reviews and perspectives), short communications, policy perspectives, and letters to the editor dealing with all aspects of conservation science, including theoretical and empirical investigations into the consequences of human actions for the diversity, structure and function of terrestrial, aquatic or marine ecosystems. Such papers may include quantitative assessments of extinction risk, fragmentation effects, spread of invasive organisms, conservation genetics, conservation management, global change effects on biodiversity, landscape or reserve design and management, restoration ecology, or resource economics. We also welcome papers coming from social sciences including those reporting on advances in conservation politics, ethics, policy, human social structure and biodiversity, and political culture among other subjects. *Biological Conservation* covers interdisciplinary topics within conservation biology and also provides practical applications of conservation research for land/resource managers and policy makers. We publish articles and thematic special issues that have a global relevance in terms of the topics or issues addressed, and thus demonstrate applications of conservation science and management beyond the specific system or species studied.Biological Conservation is an affiliate publication of the Society for Conservation Biology (SCB). SCB members can obtain a personal subscription to this journal through the Society.

2 AUDIENCE

Environmentalists, conservationists, botanists, marine scientists, ecologists, biologists, zoologists.

3 IMPACT FACTOR

2018: 4.451 © Clarivate Analytics Journal Citation Reports 2019

Environmental Periodicals Bibliography
Current Advances in Ecological Sciences
AGRICOLA
Embase
Engineering Village - GEOBASE
Current Contents - Agriculture, Biology & Environmental Sciences
Energy Information Abstracts
Biological and Agricultural Index
Science Citation Index
Cambridge Scientific Abstracts
Elsevier BIOBASE
Scopus

5 EDITORIAL BOARD

Editor-in-Chief

Vincent Devictor, UMR CNRS-UM2 5554 cc065, Institut des Sciences de l'Evolution de Montpellier

Editors

Amanda Bates, Memorial University of Newfoundland, St John's, Newfoundland and Labrador, Canada
Richard Corlett, Chinese Academy of Sciences, Menglun, Yunnan, China
Graeme Cumming, ARC Centre of Excellence for Coral Reef Studies, Townsville, Queensland, Australia
Varun R. Goswami, Conservation Initiatives, Guwahati, India
Lian Pin Koh, National University of Singapore Department of Biological Sciences, Singapore, Singapore
Rafael Loyola, Federal University of Goias, Brazil
Bea Maas, University of Vienna, Wien, Austria
Anna Pidgeon, University of Wisconsin-Madison Department of Forest and Wildlife Ecology, Madison, Wisconsin, United States
Richard B. Primack, Boston University, Boston, Massachusetts, United States
Tracey Regan, Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria, Australia
Robin Roth, University of Guelph, Guelph, Ontario, Canada

Book Review Editor

David Johns, PO Box 725, McMinneville, Oregon, OR 97218

Editorial Board

Barry Brook, The University of Adelaide, Adelaide, South Australia, Australia
Zuzana Burivalova, Princeton University, Princeton, New Jersey, United States
Regis Cereghino, Toulouse 1 University Capitole, Toulouse, France
Jin Chen, Xishuangbanna Tropical Botanical Garden, Mengla, China
Enrico Di Minin, University of Helsinki, Helsinki, Finland
Johan Ekroos, Lund University, Lund, Sweden
Markus Fischer, University of Bern, Bern, Switzerland
Travis Gallo, George Mason University, Fairfax, Virginia, United States
Kevin Gaston, University of Exeter Environment and Sustainability Institute, Penryn, United Kingdom
Laurent Godet, Coast Environment Remote Sensing Geomatics Nantes, Nantes, France
Radim Hédl, Institute of Botany Czech Academy of Sciences Department of Vegetation Ecology, Brno, Czech Republic
Zhigang Jiang, Chinese Academy of Sciences, Beijing, China
Janice Ser Huay Lee, Nanyang Technological University, Singapore, Singapore
Pia Lentini, University of Melbourne School of BioSciences, University Of Melbourne, Australia
David Lindenmayer, Australian National University, Canberra, Australia
Hong Liu, Florida International University, Miami, Florida, United States
Tessa Mazor, University of Queensland, Brisbane, Queensland, Australia
Abraham Miller-Rushing, Acadia National Park, Bar Harbor, Maine, United States
Peter Moyle, University of California Davis, Davis, California, United States
Javier Nori, National University of Cordoba, Cordoba, Argentina
Daniel Oro, Mediterranean Institute for Advanced Studies, Esporles, Spain
Ludmila Rattis, Woods Hole Research Center, Falmouth, Massachusetts, United States
Denis Allan Saunders, CSIRO Land and Water Floreat, Floreat, Australia
Christian H. Schulze, University of Vienna Faculty of Life Sciences, Vienna, Austria
Anna Sher, University of Denver, Denver, Colorado, United States
Assaf Shwartz, Technion Israel Institute of Technology, Haifa, Israel
Steve Sinclair, Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria, Australia
Fernanda Thiesen Brum, Federal University of Parana - Polytechnic Centre Campus, Curitiba,Paraná, Brazil
Anne Toomey, Pace University, New York, New York, United States
Serge Wich, Liverpool John Moores University, Liverpool, United Kingdom

5.1 *YOUR PAPER YOUR WAY*

We now differentiate between the requirements for new and revised submissions. You may choose to submit your manuscript as a single Word or PDF file to be used in the refereeing process. Only when your paper is at the revision stage, will you be requested to put your paper in to a 'correct format' for acceptance and provide the items required for the publication of your article. **To find out more, please visit the Preparation section below.**

5.2 INTRODUCTION

Please read all information carefully and follow the instructions in detail when preparing your manuscript.
Manuscripts that are not prepared according to our guidelines will be sent back to authors without review.

Biological Conservation encourages the submission of high-quality manuscripts that advance the science and practice of conservation, or which demonstrate the application of conservation principles and policy. **Conservation implications should be clearly emphasized and discussed.** Given the broad international readership of the journal, published articles should have global relevance in terms of the topics or issues addressed, and thus demonstrate applications for conservation beyond the specific system or species studied.

5.2.1 Types of paper

Word counts include text, references, figures and tables. Each figure or table should be considered equal to 300 words.

5.2.1.1 **1. Full length articles (Research papers)**

Research papers report the results of original research. The material must not have been previously published elsewhere. Full length articles are up to 8,000 words.

5.2.1.2 **2. Review articles**

Reviews summarize the status of research in a field of current interest. They may be submitted or invited. Review articles are up to 12,000 words and must include a methods section explaining how the literature for review was selected. We also consider Systematic Reviews, which apply a methodology to synthesize and appraise the scientific evidence on a specific question or hypothesis. More about systematic reviews can be found here: http://www.environmentalevidence.org/information-forauthors.

3. Perspectives:

These articles provide an opportunity for authors to present a novel, distinctive viewpoint on any subject within the journal's scope. The article should be well grounded in evidence and adequately supported by citations but may focus on a stimulating and thought-provoking line of argument that represents a significant advance in thinking about conservation problems and solutions. Perspectives articles should not exceed 8000 words.

5.2.1.3 4. Short communications

Short communications highlight both novel research and replication studies that report preliminary findings that are particularly compelling and highly relevant to conservation science and practice. If submitting a replication study, please include in your cover letter the rationale for undertaking the study. Short communications should not exceed 4,000 words.

5.2.1.4 5. Policy Analysis

These are short commentary pieces on contemporary, internationally relevant conservation or conservation-related policy issues that enable researchers, policy makers, and practitioners to make timely contributions to policy debates and actions. Contributions are based on research, expert analysis, literature review, or practitioner reflections regarding specific policy issues. Pure opinion pieces will not be considered for this paper type. Forum articles should be written in an accessible style and supported by real world examples and/or referenced scientific evidence and should not exceed 4,000 words.

5.2.1.5 6. Fast-Tracked Papers

Fast-Tracked Papers may be any of the above paper types, but are to be submitted only upon invitation from the editors. These papers will be fast-tracked by having reviewers lined up by the handling editor in advance, and upon publication these papers will be showcased in an ongoing special issue.

5.2.1.6 7. Book Reviews

Book reviews will be included in the journal on a range of relevant titles that are not more than two years old. These are usually less than 2,000 words. Please submit your requests/ideas to David Johns at johnsd@embarqmail.com.

5.2.1.7 8. Editorials

Opinion pieces by experts on a topic, usually invited by the Editor. The topic is usually timely and offers important insights into the field.

5.2.1.8 **9. Correspondence**

Letters to the Editor (Correspondence) papers are responses to recently published papers. Letters must be short (a maximum 800 words) and include only key references (5 maximum) and one figure if necessary. The content must be constructive, discuss significant issues, and respectful in tone. Provided the editors agree that publication of the letter is warranted, it will generally also receive a response from the authors of the original article, and both letter and response will be published in the same issue.

5.2.2 Submission checklist

You can use this list to carry out a final check of your submission before you send it to the journal for review. Please check the relevant section in this Guide for Authors for more details.

Ensure that the following items are present:

One author has been designated as the corresponding author with contact details:
- E-mail address
- Full postal address

All necessary files have been uploaded:
Manuscript:
- Include keywords
- All figures (include relevant captions)
- All tables (including titles, description, footnotes)
- Ensure all figure and table citations in the text match the files provided
- Indicate clearly if color should be used for any figures in print

5.2.2.1 Graphical Abstracts / Highlights files (where applicable)

Supplemental files (where applicable)

Further considerations
- Manuscript has been 'spell checked' and 'grammar checked'
- All references mentioned in the Reference List are cited in the text, and vice versa
- Permission has been obtained for use of copyrighted material from other sources (including theInternet)
- A competing interests statement is provided, even if the authors have no competing interests todeclare
- Journal policies detailed in this guide have been reviewed
- Referee suggestions and contact details provided, based on journal requirements
- We strongly encourage authors to check the existing evidences for their case at Conservation Evidence. The introduction of the paper should include a sentence highlighting whether any evidence is already available or not with corresponding references.

For further information, visit our Support Center.

5.3 BEFORE YOU BEGIN

Ethics in publishing

Please see our information pages on Ethics in publishing and Ethical guidelines for journal publication.

5.3.1 Policy and Ethics

All appropriate ethics and other approvals were obtained for the research. Where appropriate, authors should state that their research protocols have been approved by an authorized animal care or ethics committee, and include a reference to the code of practice adopted for the reported experimentation or methodology. The Editor will take account of animal welfare issues and reserves the right not to publish, especially if the research involves protocols that are inconsistent with commonly accepted norms of animal research.

5.3.2 Declaration of interest

All authors must disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/ registrations, and grants or other funding. Authors should complete the declaration of interest statement using this template and upload to the submission system at the Attach/Upload Files step. If there are no interests to declare, please choose: 'Declarations of interest: none' in the template. This statement will be published within the article if accepted. More information.

5.3.3 Submission declaration and verification

Submission of an article implies that the work described has not been published previously (except in the form of an abstract, a published lecture or academic thesis, see 'Multiple, redundant or concurrent publication' for more information), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyrightholder. To verify originality, your article may be checked by the originality detection service Crossref Similarity Check.

5.3.4 Use of inclusive language

Inclusive language acknowledges diversity, conveys respect to all people, is sensitive to differences, and promotes equal opportunities. Articles should make no assumptions about the beliefs or commitments of any reader, should contain nothing which might imply that one individual is superior to another on the grounds of race, sex, culture or any other characteristic, and should use inclusive language throughout. Authors should ensure that writing is free from bias, for instance by using 'he or she', 'his/her' instead of 'he' or 'his', and by making use of job titles that are free of stereotyping (e.g. 'chairperson' instead of 'chairman' and 'flight attendant' instead of 'stewardess').

5.3.5 Author contributions

For transparency, we encourage authors to submit an author statement file outlining their individual contributions to the paper using the relevant CRediT roles: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Roles/Writing - original draft; Writing - review & editing. Authorship statements should be formatted with the names of authors first and CRediT role(s) following. More details and an example

5.3.6 Changes to authorship

Authors are expected to consider carefully the list and order of authors **before** submitting their manuscript and provide the definitive list of authors at the time of the original submission. Any addition, deletion or rearrangement of author names in the authorship list should be made only **before** the manuscript has been accepted and only if approved by the journal Editor. To request such a change, the Editor must receive the following from the **corresponding author**: (a) the reason for the change in author list and (b) written confirmation (e-mail, letter) from all authors that they agree with the addition, removal or rearrangement. In the case of addition or removal of authors, this includes confirmation from the author being added or removed.

Only in exceptional circumstances will the Editor consider the addition, deletion or rearrangement of authors **after** the manuscript has been accepted. While the Editor considers the request, publication of the manuscript will be suspended. If the manuscript has already been published in an online issue, any requests approved by the Editor will result in a corrigendum.

5.3.6.1 Article transfer service

This journal is part of our Article Transfer Service. This means that if the Editor feels your article is more suitable in one of our other participating journals, then you may be asked to consider transferring the article to one of those. If you agree, your article will be transferred automatically on your behalf with no need to reformat. Please note that your article will be reviewed again by the new journal. More information.

5.3.7 Copyright

Upon acceptance of an article, authors will be asked to complete a 'Journal Publishing Agreement' (see more information on this). An e-mail will be sent to the corresponding author confirming receipt of the manuscript together with a 'Journal Publishing Agreement' form or a link to the online version of this agreement.

Subscribers may reproduce tables of contents or prepare lists of articles including abstracts for internal circulation within their institutions. Permission of the Publisher is required for resale or distribution outside the institution and for all other derivative works, including compilations and translations. If excerpts from other copyrighted works are included, the author(s) must obtain written permission from the copyright owners and credit the source(s) in the article. Elsevier has preprinted forms for use by authors in these cases.

For gold open access articles: Upon acceptance of an article, authors will be asked to complete an 'Exclusive License Agreement' (more information). Permitted third party reuse of gold open access articles is determined by the author's choice of user license.

Author rights

As an author you (or your employer or institution) have certain rights to reuse your work. More information.

Elsevier supports responsible sharing

Find out how you can share your research published in Elsevier journals.

5.3.8 Role of the funding source

You are requested to identify who provided financial support for the conduct of the research and/or preparation of the article and to briefly describe the role of the sponsor(s), if any, in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication. If the funding source(s) had no such involvement then this should be stated.

5.3.9 Open access

Please visit our Open Access page for more information.

5.3.9.1 Elsevier Researcher Academy

Researcher Academy is a free e-learning platform designed to support early and mid-career researchers throughout their research journey. The "Learn" environment at Researcher Academy offers several interactive modules, webinars, downloadable guides and resources to guide you through the process of writing for research and going through peer review. Feel free to use these free resources to improve your submission and navigate the publication process with ease.

5.3.9.2 Language (usage and editing services)

Please write your text in good English (American or British usage is accepted, but not a mixture of these). Authors who feel their English language manuscript may require editing to eliminate possible grammatical or spelling errors and to conform to correct scientific English may wish to use the English Language Editing service available from Elsevier's Author Services.

5.3.10 Submission

Our online submission system guides you stepwise through the process of entering your article details and uploading your files. The system converts your article files to a single PDF file used in the peer-review process. Editable files (e.g., Word, LaTeX) are required to typeset your article for final publication. All correspondence, including notification of the Editor's decision and requests for revision, is sent by e-mail.

5.3.11 Referees

Authors are at liberty to suggest the names of up to three potential reviewers (with full contact details). Potential reviewers should not include anyone with whom the authors have collaborated during the research being submitted.

5.3.12 Additional Information

5.3.12.1 **Editorial Process**

Publishing space in the journal is limited, such that many manuscripts must be rejected. To expedite the processing of manuscripts, the journal has adopted a two-tier review process. During the first stage of review, the handling editor evaluates the manuscript for appropriateness and scientific content, taking advice where appropriate from members of the editorial board. Criteria for rejection at this stage include: **Manuscript lacks a strong conservation focus or theme, or**

management implications not well-developed. Please note that research on a rare or endangered species or ecosystem is not sufficient justification to merit publication in Biological Conservation. Published research must also advance the science and practice of conservation biology, and thus have broader application for a wide international audience.**Manuscript subject matter more appropriate for another journal.** Natural history or biodiversity surveys, including site descriptions, are usually better suited for other outlets, such as a regional or taxon-specific journal. Similarly, manuscripts with a primarily behavioral, genetic or ecological focus are more appropriate for journals in those fields. For example, studies reporting on disturbance effects, species interactions (e.g., predatorprey, competitive, or pollinator-host plant interactions), species-habitat relationships, descriptive genetics (e.g., assays of genetic variation within or between populations), or behavioral responses to disturbance will be referred elsewhere if they lack a clear conservation message. Authors are advised to contact an Editor prior to submission if there are any questions regarding the appropriateness of a manuscript for the journal.**Study primarily of local or regional interest.** *Biological Conservation* is international in scope, and thus research published in the journal should have global relevance, in terms of the topics or issues addressed.**Study poorly designed or executed.** Research lacks spatial or temporal replication, has insufficient sample sizes, or inadequate data analysis. Such obvious indications of poor-quality science will be cause for immediate rejection.**Manuscript poorly written.** Poor writing interferes with the effective communication of science. Authors for whom English is not the first language are advised to consult with a technical language editor before submission.**Conservation research ethics violated.** Research was unnecessarily destructive, was conducted for the express purpose of causing harm/mortality (e.g., simulation of treatment or disturbance effects on survivorship), or violated ethics in the treatment and handling of animals. Where appropriate, authors must provide a statement and supporting documentation that research was approved by the authors' institutional animal care and use committee(s).Manuscripts that pass this first stage of editorial review are then subjected to a second stage of formal peer review. This involves evaluation of the manuscript by at least two specialists within the field of study, which may include one or more members of the editorial board. Beyond a critical assessment of the scientific content and overall presentation, referees are asked to evaluate the originality, likely impact and global relevance of the research. Referees make a recommendation to the handling editor, but note that it is ultimately the decision of the handling editor as to whether a manuscript is accepted for publication in *Biological Conservation*.

5.3.12.2 **Editor-in-Chief Dr. Vincent Devictor**

UMR CNRS-UM2 5554 cc065,
Institut des Sciences de l'Evolution de Montpellier,
Place Eugène Bataillon, 34090 Montpellier,
France
Email: vincent.devictor@univ-montp2.fr

5.3.12.3 **Editors**

5.4 PREPARATION

5.4.1 NEW SUBMISSIONS

Submission to this journal proceeds totally online and you will be guided stepwise through the creation and uploading of your files. The system automatically converts your files to a single PDF file, which is used in the peer-review process.
As part of the Your Paper Your Way service, you may choose to submit your manuscript as a single file to be used in the refereeing process. This can be a PDF file or a Word document, in any format or layout that can be used by referees to evaluate your manuscript. It should contain high enough quality figures for refereeing. If you prefer to do so, you may still provide all or some of the source files at the initial submission. Please note that individual figure files larger than 10 MB must be

uploaded separately.

Please use correct, continuous line numbering and page numbering throughout the document.

5.4.1.1 References

There are no strict requirements on reference formatting at submission. References can be in any style or format as long as the style is consistent. Where applicable, author(s) name(s), journal title/ book title, chapter title/article title, year of publication, volume number/book chapter and the article number or pagination must be present. Use of DOI is highly encouraged. The reference style used by the journal will be applied to the accepted article by Elsevier at the proof stage. Note that missing data will be highlighted at proof stage for the author to correct.

5.4.1.2 Formatting requirements

There are no strict formatting requirements but all manuscripts must contain the essential elements needed to convey your manuscript, for example Abstract, Keywords, Introduction, Materials and Methods, Results, Conclusions, Artwork and Tables with Captions.

If your article includes any Videos and/or other Supplementary material, this should be included in your initial submission for peer review purposes. Divide the article into clearly defined sections.

5.4.1.3 Tables and Figures

Please place legends above Tables and below Figures. They should follow the References at the end of the manuscript.

5.4.2 Peer review

This journal operates a double blind review process. All contributions will be initially assessed by the editor for suitability for the journal. Papers deemed suitable are then typically sent to a minimum of two independent expert reviewers to assess the scientific quality of the paper. The Editor is responsible for the final decision regarding acceptance or rejection of articles. The Editor's decision is final. More information on types of peer review.

5.4.3 Double-blind review

This journal uses double-blind review, which means the identities of the authors are concealed from the reviewers, and vice versa. More information is available on our

website. To facilitate this, please include the following separately:
Title page (with author details): This should include the title, authors' names, affiliations, acknowledgements and any Declaration of Interest statement, and a complete address for the corresponding author including an e-mail address.
Blinded manuscript (no author details): The main body of the paper (including the references, figures, tables and any acknowledgements) should not include any identifying information, such as the authors' names or affiliations.

5.4.4 REVISED SUBMISSIONS

5.4.4.1 Use of word processing software

Please use correct, continuous line numbering and page numbering throughout the document.

It is important that the file be saved in the native format of the word processor used. The text should be in single-column format. Keep the layout of the text as simple as possible. Most formatting codes will be removed and replaced on processing the article. In particular, do not use the word processor's options to justify text or to hyphenate words. However, do use bold face, italics, subscripts, superscripts etc. When preparing tables, if you are using a table grid, use only one grid for each individual table and not a grid for each row. If no grid is used, use tabs, not spaces, to align columns. The electronic text should be prepared in a way very similar to that of conventional manuscripts (see also the Guide to Publishing with Elsevier: https://www.elsevier.com/guidepublication). Note that source files of figures, tables and text graphics will be required whether or not you embed your figures in the text. See also the section on Electronic artwork.
To avoid unnecessary errors you are strongly advised to use the 'spell-check' and 'grammar-check' functions of your word processor.

Please use single spacing throughout the document. Use continuous line numbering throughout the document. Avoid full justification, i.e., do not use a constant right-hand margin. Ensure that each new paragraph is clearly indicated. Number every page of the manuscript, including the title page, references tables, etc. Present tables and figure legends on separate pages at the end of the manuscript. Layout and conventions must conform with those given in this guide to authors. **Journal style has changed over time so do not use old issues as a guide.** Number all pages consecutively. Italics are not to be used for expressions of Latin origin, for example, in vivo, et al., per se. Use decimal points (not commas); use a space for thousands (10 000 and above).

5.4.4.2 Use of word processing software

Regardless of the file format of the original submission, at revision you must provide us with an editable file of the entire article. Keep the layout of the text as simple as

possible. Most formatting codes will be removed and replaced on processing the article. The electronic text should be prepared in a way very similar to that of conventional manuscripts (see also the Guide to Publishing with Elsevier). See also the section on Electronic artwork.
To avoid unnecessary errors you are strongly advised to use the 'spell-check' and 'grammar-check' functions of your word processor.

5.4.5 Cover letter

Submission of a manuscript must be accompanied by a cover letter that includes the following statements or acknowledgements: The work is all original research carried out by the authors.All authors agree with the contents of the manuscript and its submission to the journal.No part of the research has been published in any form elsewhere, unless it is fully acknowledged in the manuscript. Authors should disclose how the research featured in the manuscript relates to any other manuscript of a similar nature that they have published, in press, submitted or will soon submit to Biological Conservation or elsewhere.The manuscript is not being considered for publication elsewhere while it is being considered for publication in this journal.Any research in the paper not carried out by the authors is fully acknowledged in the manuscript.All sources of funding are acknowledged in the manuscript, and authors have declared any direct financial benefits that could result from publication.All appropriate ethics and other approvals were obtained for the research. Where appropriate, authors should state that their research protocols have been approved by an authorized animal care or ethics committee, and include a reference to the code of practice adopted for the reported experimentation or methodology. The Editor will take account of animal welfare issues and reserves the right not to publish, especially if the research involves protocols that are inconsistent with commonly accepted norms of animal research.Please include a short paragraph that describes the main finding of your paper, and its significance to the field of conservation biology.The authors should state in the cover letter if the paper in any form has previously been submitted to *Biological Conservation*. In that case the authors should specify the original manuscript number.

5.4.6 Article structure

5.4.6.1 Subdivision - numbered sections

Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line.

5.4.6.2 Introduction

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

5.4.6.3 Material and methods

Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized, and indicated by a reference. If quoting directly from a previously published method, use quotation marks and also cite the source. Any modifications to existing methods should also be described.

5.4.6.4 Theory/calculation

A Theory section should extend, not repeat, the background to the article already dealt with in the Introduction and lay the foundation for further work. In contrast, a Calculation section represents a practical development from a theoretical basis.

Results

Results should be clear and concise.

5.4.6.5 Discussion

This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

5.4.6.6 Conclusions

The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

Glossary

Please supply, as a separate list, the definitions of field-specific terms used in your article.

5.4.6.7 Appendices

If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq.

(A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.1, etc.

5.4.7 Essential title page information

- ***Title.*** Concise and informative, yet not overly general. If appropriate, include the species or ecosystem that was the subject of the study, or the location where the study was done. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible
- ***Author names and affiliations.*** Where the family name may be ambiguous (e.g., a double name), please indicate this clearly. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.
- ***Corresponding author.*** Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. **Ensure that phone numbers (with country and area code) are provided in addition to the e-mail address and the complete postal address. Contact details must be kept up to date by the corresponding author.**
- ***Present/permanent address.*** If an author has moved since the work described in the article was done, or was visiting at the time, a 'Present address' (or 'Permanent address') may be indicated as a footnote to that author's name. The address at which the author actually did the work must be retained as the main, affiliation address. Superscript Arabic numerals are used for such footnotes.

5.4.8 Highlights

Highlights are mandatory for this journal as they help increase the discoverability of your article via search engines. They consist of a short collection of bullet points that capture the novel results of your research as well as new methods that were used during the study (if any). Please have a look at the examples here: example Highlights.

Highlights should be submitted in a separate editable file in the online submission system. Please use 'Highlights' in the file name and include 3 to 5 bullet points (maximum 85 characters, including spaces, per bullet point).

5.4.9 Abstract

A concise and factual abstract is required (maximum length of 250 words). The abstract should state briefly the purpose of the research, the methods used, the principal results and major conclusions. Please try to keep each sentence as specific as possible, and avoid such general statements as "The management implications of the results are discussed". An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, they must be cited in full, without reference to the reference list. Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

5.4.9.1 Graphical abstract

Although a graphical abstract is optional, its use is encouraged as it draws more attention to the online article. The graphical abstract should summarize the contents of the article in a concise, pictorial form designed to capture the attention of a wide readership. Graphical abstracts should be submitted as a separate file in the online submission system. Image size: Please provide an image with a minimum of 531 × 1328 pixels (h × w) or proportionally more. The image should be readable at a size of 5 × 13 cm using a regular screen resolution of 96 dpi. Preferred file types: TIFF, EPS, PDF or MS Office files. You can view Example Graphical Abstracts on our information site.
Authors can make use of Elsevier's Illustration Services to ensure the best presentation of their images and in accordance with all technical requirements.

5.4.9.2 Stereochemistry abstract

For each important chiral compound you are requested to supply a stereochemistry abstract detailing structure, name, formula and all available stereochemical information for eventual incorporation into a database. An abstract for only one enantiomer per compound is required.

5.4.10 Keywords

Immediately after the abstract, provide a maximum of 6 keywords, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and', 'of'). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

5.4.10.1 Abbreviations

Define abbreviations that are not standard in this field in a footnote to be placed on the first page of the article. Such abbreviations that are unavoidable in the abstract must be defined at their first mention there, as well as in the footnote. Ensure consistency of abbreviations throughout the article.

5.4.10.2 Acknowledgements

Collate acknowledgements in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof reading the article, etc.).

5.4.10.3 Formatting of funding sources

List funding sources in this standard way to facilitate compliance to funder's requirements:
Funding: This work was supported by the National Institutes of Health [grant numbers xxxx, yyyy]; the Bill & Melinda Gates Foundation, Seattle, WA [grant number zzzz]; and the United States Institutes of Peace [grant number aaaa].

It is not necessary to include detailed descriptions on the program or type of grants and awards. When funding is from a block grant or other resources available to a university, college, or other research institution, submit the name of the institute or organization that provided the funding.

If no funding has been provided for the research, please include the following sentence:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

5.4.11 Nomenclature and Units

Follow internationally accepted rules and conventions: use the international system of units (SI) for all scientific and laboratory data. If other quantities are mentioned, give their equivalent in SI.

Common names must be in lower-case except proper nouns. All common names must be followed by a scientific name in parentheses in italics. For example, bottlenose dolphin (*Tursiops aduncus*). Where scientific names are used in preference to common names they should be in italics and the genus should be reduced to the first letter after the first mention. For example, the first mention is given as Tursiops aduncus and subsequent mentions are given as *T. aduncus*.

5.4.11.1 Math formulae

Please submit math equations as editable text and not as images. Present simple formulae in line with normal text where possible and use the solidus (/) instead of a horizontal line for small fractional terms, e.g., X/Y. In principle, variables are to be presented in italics. Powers of e are often more conveniently denoted by exp. Number consecutively any equations that have to be displayed separately from the text (if referred to explicitly in the text).

5.4.11.2 Footnotes

Footnotes should be used sparingly. Number them consecutively throughout the article. Many word processors build footnotes into the text, and this feature may be used. Should this not be the case, indicate the position of footnotes in the text and present the footnotes themselves separately at the end of the article.

5.4.12 Artwork

5.4.12.1 Electronic artwork General points

- Make sure you use uniform lettering and sizing of your original artwork.
- Preferred fonts: Arial (or Helvetica), Times New Roman (or Times), Symbol, Courier.
- Number the illustrations according to their sequence in the text.
- Use a logical naming convention for your artwork files.
- Indicate per figure if it is a single, 1.5 or 2-column fitting image.
- For Word submissions only, you may still provide figures and their captions, and tables within asingle file at the revision stage.
- Please note that individual figure files larger than 10 MB must be provided in separate source files.

A detailed guide on electronic artwork is available.

5.4.12.2 **You are urged to visit this site; some excerpts from the detailed information are given here.** Formats

Regardless of the application used, when your electronic artwork is finalized, please 'save as' or convert the images to one of the following formats (note the resolution requirements for line drawings, halftones, and line/halftone combinations given below):
EPS (or PDF): Vector drawings. Embed the font or save the text as 'graphics'.
TIFF (or JPG): Color or grayscale photographs (halftones): always use a minimum of 300 dpi.
TIFF (or JPG): Bitmapped line drawings: use a minimum of 1000 dpi.
TIFF (or JPG): Combinations bitmapped line/half-tone (color or grayscale): a minimum of 500 dpi is required.

Please do not:

- Supply files that are optimized for screen use (e.g., GIF, BMP, PICT, WPG); the resolution is too low.
- Supply files that are too low in resolution.
- Submit graphics that are disproportionately large for the content.

5.4.12.2.1 Color artwork

Please make sure that artwork files are in an acceptable format (TIFF (or JPEG), EPS (or PDF), or MS Office files) and with the correct resolution. If, together with your accepted article, you submit usable color figures then Elsevier will ensure, at no additional charge, that these figures will appear in color online (e.g., ScienceDirect and other sites) regardless of whether or not these illustrations are reproduced in color in the printed version. **For color reproduction in print, you will receive information regarding the costs from Elsevier after receipt of your accepted article**. Please indicate your preference for color: in print or online only. Further information on the preparation of electronic artwork.

5.4.12.2.2 Figure captions

Ensure that each illustration has a caption. A caption should comprise a brief title (**not** on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used.

5.4.13 Tables

Please submit tables as editable text and not as images. Tables can be placed either next to the relevant text in the article, or on separate page(s) at the end. Number tables consecutively in accordance with their appearance in the text and place any table notes below the table body. Be sparing in the use of tables and ensure that the data presented in them do not duplicate results described elsewhere in the article. Please avoid using vertical rules and shading in table cells.

5.4.14 References

5.4.15 Citation in text

Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Any references cited in the abstract must be given in full. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either 'Unpublished results' or 'Personal communication'. Citation of a reference as 'in press' implies that the item has been accepted for publication.

5.4.15.1 Reference links

Increased discoverability of research and high quality peer review are ensured by online links to the sources cited. In order to allow us to create links to abstracting and indexing services, such as Scopus, CrossRef and PubMed, please ensure that data provided in the references are correct. Please note that incorrect surnames, journal/book titles, publication year and pagination may prevent link creation. When copying references, please be careful as they may already contain errors. Use of the DOI is highly encouraged.

A DOI is guaranteed never to change, so you can use it as a permanent link to any electronic article. An example of a citation using DOI for an article not yet in an issue is: VanDecar J.C., Russo R.M., James D.E., Ambeh W.B., Franke M. (2003). Aseismic continuation of the Lesser Antilles slab beneath northeastern Venezuela. Journal of Geophysical Research, https://doi.org/10.1029/2001JB000884. Please note the format of such citations should be in the same style as all other references in the paper.

5.4.15.2 Web references

As a minimum, the full URL should be given and the date when the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately (e.g., after the reference list) under a different heading if desired, or can be included in the reference list.

5.4.15.3 Data references

This journal encourages you to cite underlying or relevant datasets in your manuscript by citing them in your text and including a data reference in your Reference List. Data references should include the following elements: author name(s), dataset title, data repository, version (where available), year, and global persistent identifier. Add [dataset] immediately before the reference so we can properly identify it as a data reference. The [dataset] identifier will not appear in your published article.

5.4.15.4 References in a special issue

Please ensure that the words 'this issue' are added to any references in the list (and any citations in the text) to other articles in the same Special Issue.

5.4.15.5 Reference management software

Most Elsevier journals have their reference template available in many of the most popular reference management software products. These include all products that support Citation Style Language styles, such as Mendeley. Using citation plug-ins from these products, authors only need to select the appropriate journal template when preparing their article, after which citations and bibliographies will be automatically formatted in the journal's style. If no template is yet available for this journal, please follow the format of the sample references and citations as shown in this Guide. If you use reference management software, please ensure that you remove all field codes before submitting the electronic manuscript. More information on how to remove field codes from different reference management software.

Users of Mendeley Desktop can easily install the reference style for this journal by clicking the following link:
http://open.mendeley.com/use-citation-style/biological-conservation
When preparing your manuscript, you will then be able to select this style using the Mendeley plugins for Microsoft Word or LibreOffice.

5.4.15.6 Reference formatting

There are no strict requirements on reference formatting at submission. References can be in any style or format as long as the style is consistent. Where applicable, author(s) name(s), journal title/ book title, chapter title/article title, year of publication, volume number/book chapter and the article number or pagination must be present. Use of DOI is highly encouraged. The reference style used by the journal will be applied to the accepted article by Elsevier at the proof stage. Note that missing data will be highlighted at proof stage for the author to correct. If you do wish to format the references yourself they should be arranged according to the following examples:

5.4.15.7 Reference style

Text: All citations in the text should refer to:

1. *Single author:* the author's name (without initials, unless there is ambiguity) and the year of publication;
2. *Two authors:* both authors' names and the year of publication;
3. *Three or more authors:* first author's name followed by 'et al.' and the year of publication. Citations may be made directly (or parenthetically). Groups of references can be listed either first alphabetically, then chronologically, or vice versa.

Examples: 'as demonstrated (Allan, 2000a, 2000b, 1999; Allan and Jones, 1999)…. Or, as demonstrated (Jones, 1999; Allan, 2000)… Kramer et al. (2010) have recently shown …'

List: References should be arranged first alphabetically and then further sorted chronologically if necessary. More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c', etc., placed after the year of publication.

Examples:

Reference to a journal publication:

Van der Geer, J., Hanraads, J.A.J., Lupton, R.A., 2010. The art of writing a scientific article. J. Sci.

Commun. 163, 51–59. https://doi.org/10.1016/j.Sc.2010.00372.

Reference to a journal publication with an article number:

Van der Geer, J., Hanraads, J.A.J., Lupton, R.A., 2018. The art of writing a scientific article. Heliyon. 19, e00205. https://doi.org/10.1016/j.heliyon.2018.e00205.

Reference to a book:

Strunk Jr., W., White, E.B., 2000. The Elements of Style, fourth ed. Longman, New York.

Reference to a chapter in an edited book:

Mettam, G.R., Adams, L.B., 2009. How to prepare an electronic version of your article, in: Jones, B.S., Smith , R.Z. (Eds.), Introduction to the Electronic Age. E-Publishing Inc., New York, pp. 281–304.

Reference to a website:

Cancer Research UK, 1975. Cancer statistics reports for the UK. http://www.cancerresearchuk.org/ aboutcancer/statistics/cancerstatsreport/ (accessed 13 March 2003).

Reference to a dataset:

[dataset] Oguro, M., Imahiro, S., Saito, S., Nakashizuka, T., 2015. Mortality data for Japanese oak wilt disease and surrounding forest compositions. Mendeley Data, v1. https://doi.org/10.17632/ xwj98nb39r.1.

5.4.16 Video

Elsevier accepts video material and animation sequences to support and enhance your scientific research. Authors who have video or animation files that they wish to submit with their article are strongly encouraged to include links to these within the body of the article. This can be done in the same way as a figure or table by referring to the video or animation content and noting in the body text where it should be placed. All submitted files should be properly labeled so that they directly relate to the video file's content. In order to ensure that your video or animation material is directly usable, please provide the file in one of our recommended file formats with a preferred maximum size of 150 MB per file, 1 GB in total. Video and animation files supplied will be published online in the electronic version of your article in Elsevier Web products, including ScienceDirect. Please supply 'stills' with your files: you can choose any frame from the video or animation or make a separate image. These will be used instead of standard icons and will personalize the link to your video data. For more detailed instructions please visit our video instruction pages. Note: since video and animation cannot be embedded in the print version of the journal, please provide text for both the electronic and the print version for the portions of the article that refer to this content.

5.4.17 Data visualization

Include interactive data visualizations in your publication and let your readers interact and engage more closely with your research. Follow the instructions here to find out about available data visualization options and how to include them with your article.

5.4.18 Supplementary material

Supplementary material such as applications, images and sound clips, can be published with your article to enhance it. Submitted supplementary items are published exactly as they are received (Excel or PowerPoint files will appear as such online). Please submit your material together with the article and supply a concise, descriptive caption for each supplementary file. If you wish to make changes to supplementary material during any stage of the process, please make sure to provide an updated file. Do not annotate any corrections on a previous version. Please switch off the 'Track Changes' option in Microsoft Office files as these will appear in the published version.

The supplementary material should be cited as an online Appendix to the paper, usually in the Methods. If it contains several tables, images and/or figures, these should be cited as Table A1, Figure A1 and so on.

Authors are strongly encouraged to make the data supporting their paper available to readers through an open-access data repository and/or as an Appendix to the paper. For more details on journal data policy see the paragraphs on *Data Depositing and Linking to and depositing data at PANGAEA.*

5.4.18.1 **Data Depositing**

Ideally, data should be freely available online through a specialist data centre that provides a permanent archive (repository) for the dataset, and may integrate the data with other datasets using international standards. Examples include PANGAEA, and GBIF and its major contributors such as OBIS and VertNet. Some Ocean Data Centres may also provide this service. Where such a data centre does not exist, we ask that the data be made freely available online from a permanent archive (repository). Where possible, it should follow international data standards. This may be an institutional repository for its staff. The data should be accompanied by sufficient information (metadata) for the reader to understand its composition and origins, and determine if it is fit for their purpose. In particular, the data should allow the results of the publication to be reproduced. Data being downloadable from departmental or personal websites is not regarded as permanently archived.

5.4.19 Research data

This journal encourages and enables you to share data that supports your research

publication where appropriate, and enables you to interlink the data with your published articles. Research data refers to the results of observations or experimentation that validate research findings. To facilitate reproducibility and data reuse, this journal also encourages you to share your software, code, models, algorithms, protocols, methods and other useful materials related to the project.
Below are a number of ways in which you can associate data with your article or make a statement about the availability of your data when submitting your manuscript. If you are sharing data in one of these ways, you are encouraged to cite the data in your manuscript and reference list. Please refer to the "References" section for more information about data citation. For more information on depositing, sharing and using research data and other relevant research materials, visit the research data page.

5.4.19.1 Data linking

If you have made your research data available in a data repository, you can link your article directly to the dataset. Elsevier collaborates with a number of repositories to link articles on ScienceDirect with relevant repositories, giving readers access to underlying data that gives them a better understanding of the research described.

There are different ways to link your datasets to your article. When available, you can directly link your dataset to your article by providing the relevant information in the submission system. For more information, visit the database linking page.

For supported data repositories a repository banner will automatically appear next to your published article on ScienceDirect.

In addition, you can link to relevant data or entities through identifiers within the text of your manuscript, using the following format: Database: xxxx (e.g., TAIR: AT1G01020; CCDC: 734053; PDB: 1XFN).

5.4.19.2 Mendeley Data

This journal supports Mendeley Data, enabling you to deposit any research data (including raw and processed data, video, code, software, algorithms, protocols, and methods) associated with your manuscript in a free-to-use, open access repository. During the submission process, after uploading your manuscript, you will have the opportunity to upload your relevant datasets directly to *Mendeley Data*. The datasets will be listed and directly accessible to readers next to your published article online.

For more information, visit the Mendeley Data for journals page.

5.4.19.3 Data in Brief

You have the option of converting any or all parts of your supplementary or additional raw data into one or multiple data articles, a new kind of article that houses and describes your data. Data articles ensure that your data is actively reviewed, curated, formatted, indexed, given a DOI and publicly available to all upon publication. You are encouraged to submit your article for *Data in Brief* as an additional item directly alongside the revised version of your manuscript. If your research article is accepted, your data article will automatically be transferred over to *Data in Brief* where it will be editorially reviewed and published in the open access data journal, *Data in Brief*. Please note an open access fee of 600 USD is payable for publication in *Data in Brief*. Full details can be found on the Data in Brief website. Please use this template to write your Data in Brief.

5.4.19.4 MethodsX

You have the option of converting relevant protocols and methods into one or multiple MethodsX articles, a new kind of article that describes the details of customized research methods. Many researchers spend a significant amount of time on developing methods to fit their specific needs or setting, but often without getting credit for this part of their work. MethodsX, an open access journal, now publishes this information in order to make it searchable, peer reviewed, citable and reproducible. Authors are encouraged to submit their MethodsX article as an additional item directly alongside the revised version of their manuscript. If your research article is accepted, your methods article will automatically be transferred over to MethodsX where it will be editorially reviewed. Please note an open access fee is payable for publication in MethodsX. Full details can be found on the MethodsX website. Please use this template to prepare your MethodsX article.

5.4.19.5 Data statement

To foster transparency, we encourage you to state the availability of your data in your submission. This may be a requirement of your funding body or institution. If your data is unavailable to access or unsuitable to post, you will have the opportunity to indicate why during the submission process, for example by stating that the research data is confidential. The statement will appear with your published article on ScienceDirect. For more information, visit the Data Statement page.

5.5 AFTER ACCEPTANCE

5.5.1 Online proof correction

To ensure a fast publication process of the article, we kindly ask authors to provide us with their proof corrections within two days. Corresponding authors will receive an e-mail with a link to our online proofing system, allowing annotation and correction of proofs online. The environment is similar to MS Word: in addition to editing text, you can also comment on figures/tables and answer questions from the Copy Editor. Web-based proofing provides a faster and less error-prone process by allowing you to directly type your corrections, eliminating the potential introduction of errors.

If preferred, you can still choose to annotate and upload your edits on the PDF version. All instructions for proofing will be given in the e-mail we send to authors, including alternative methods to the online version and PDF.

We will do everything possible to get your article published quickly and accurately. Please use this proof only for checking the typesetting, editing, completeness and correctness of the text, tables and figures. Significant changes to the article as accepted for publication will only be considered at this stage with permission from the Editor. It is important to ensure that all corrections are sent back to us in one communication. Please check carefully before replying, as inclusion of any subsequent corrections cannot be guaranteed. Proofreading is solely your responsibility.

5.5.2 Offprints

The corresponding author will, at no cost, receive a customized Share Link providing 50 days free access to the final published version of the article on ScienceDirect. The Share Link can be used for sharing the article via any communication channel, including email and social media. For an extra charge, paper offprints can be ordered via the offprint order form which is sent once the article is accepted for publication. Both corresponding and co-authors may order offprints at any time via Elsevier's Author Services. Corresponding authors who have published their article gold open access do not receive a Share Link as their final published version of the article is available open access on ScienceDirect and can be shared through the article DOI link.

5.6 AUTHOR INQUIRIES

Visit the Elsevier Support Center to find the answers you need. Here you will find everything from Frequently Asked Questions to ways to get in touch.

You can also check the status of your submitted article or find out when your accepted article will be published.

ANEXO D

Declaração de tradução profissional do capítulo 1

CERTIFICATE

To the Editorial Board

This is to certify that the paper “**THIRTY-SIX YEARS OF RESERACH ON BATS IN THE REGION OF LONDRINA, BRAZIL: WHAT HAVE WE LEARNT?**” by Carolina Blefari Batista, Isaac Passos de Lima and Marcos Robalinho Lima, was translated by the undersigned, who is a native speaker of English. The translation is grammatically and stylistically to standard.

Maringá PR Brazil, 22nd April 2020.

Yours truly,

Bonnici

Dr. Thomas Bonnici
I.D. card 563 250
Department of English, State University of Maringá, Maringá PR Brazil.

ANEXO E

Declaração de tradução profissional do capítulo 3

CERTIFICATE

To the Editorial Board

This is to certify that the paper “**DOWNSCALING THE ATLANTIC FOREST BIODIVERSITY HOTSPOT: USING THE DISTRIBUTION OF BATS TO FIND SMALLER HOTSPOTS OF CONSERVATION PRIORITY”,** by Carolina Blefari Batista, Isaac Passos de Lima, Rafael Arruda and Marcos Robalinho Lima, was translated by the undersigned, who is a native speaker of English. The translation is grammatically and stylistically to standard.

Maringá PR Brazil, 25th April 2020.

Yours truly,

Bonnici

Dr. Thomas Bonnici
I.D. card 563 250
Department of English, State University of Maringá, Maringá PR Brazil.